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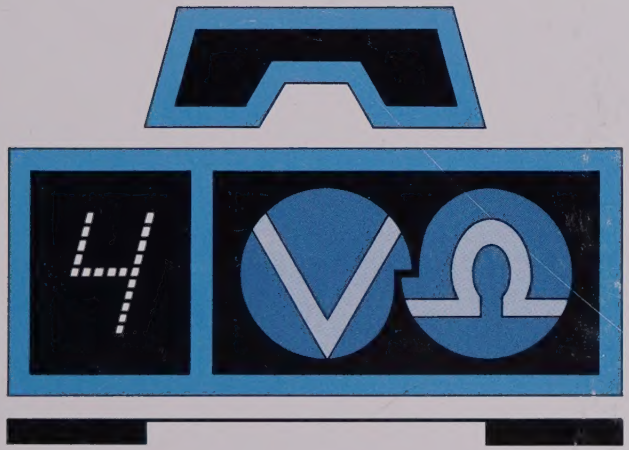
INSTRUCTION MANUAL

4324

DIGITAL MULTIMETER



DANA®

PUBLICATION NO. 980452

INSTRUCTION MANUAL

MODEL 4324

DIGITAL MULTIMETER

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DANA®

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TELETYPE 910-595-1136
TELEX 678-341

PUBLICATION DATE: AUGUST 1976

WARRANTY

Within one year of purchase, Dana Laboratories will repair or replace your instrument, at our option, if in any way it is defective in material or workmanship. All parts and labor charges will be paid by Dana Laboratories. Just call Dana Product Service at (714)833-1234 collect in California, for assistance. We will advise the proper shipping address for your prepaid shipment. Your instrument will be returned to you freight prepaid.

NOTE

Dana buys the best batteries obtainable from battery manufacturers and each unit is tested before installation in the DMM. However, due to inherent variance between individual cells and unpredictability of charge-discharge patterns, batteries are specifically excluded from the Dana parts warranty.

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FOR YOUR SAFETY

Before undertaking any maintenance procedure, whether it be a specific troubleshooting or maintenance procedure described herein or an exploratory procedure aimed at determining whether there has been a malfunction, read the applicable section of this manual and note carefully the WARNING and CAUTION notices contained therein.

The equipment described in this manual contains voltages hazardous to human life and safety and which is capable of inflicting personal injury. The cautionary and warning notes are included in this manual to alert operator and maintenance personnel to the electrical hazards and thus prevent personal injury and damage to equipment.

If this instrument is to be powered from the AC Mains through an autotransformer (such as a Variac or equivalent) ensure that the instrument common connector is connected to the ground (earth) connection of the power mains.

Before operating the unit ensure that the protective conductor (green wire) is connected to the ground (earth) protective conductor of the power outlet. Do not defeat the protective feature of the third protective conductor in the power cord by using a two conductor extension cord or a three-prong/two-prong adapter.

Maintenance and calibration procedures contained in this manual sometimes call for operation of the unit with power applied and protective covers removed. Read the procedures carefully and heed Warnings to avoid "live" circuit points to ensure your personal safety.

Before operating this instrument.

1. Ensure that the instrument is configured to operate on the voltage available at the power source. See Installation section.
2. Ensure that the proper fuse is in place in the instrument for the power source on which the instrument is to be operated.
3. Ensure that all other devices connected to or in proximity to this instrument are properly grounded or connected to the protective third-wire earth ground.

FOR YOUR SAFETY

Congratulations on your choice of a Dana instrument. . . . . .

Now that you are using the instrument, Dana would like to help you to take full advantage of its capabilities.

To do this, Dana issues addendum sheets, revision sheets, and application data sheets to be included in your instruction manual. To see that these reach you, please fill in and return the reply card below. In the event that you have received a preliminary instruction manual, the return of the card will ensure your receiving a final manual as soon as it is available.

Dana Laboratories manufactures a complete line of digital voltmeters, data amplifiers, frequency counters, and frequency synthesizers. Catalogs are available; to get your copy, simply check the appropriate box on the reply card.

To keep my instruction manual updated, please send revision pages, application data, or other supplementary information to:

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My Dana instrument is a _____, Model _____

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ERRATA SHEET

October 25, 1976

Add the following CAUTION following paragraph 2.14 on page 2-3.

CAUTION

Do not charge the batteries with the FUNCTION switch in the OFF position when a BATTERY DISCHARGED condition is indicated. Charge the batteries with the FUNCTION switch set to one of the on positions such as ACV, DCV or KΩ. Charging at a high rate shortens battery life.

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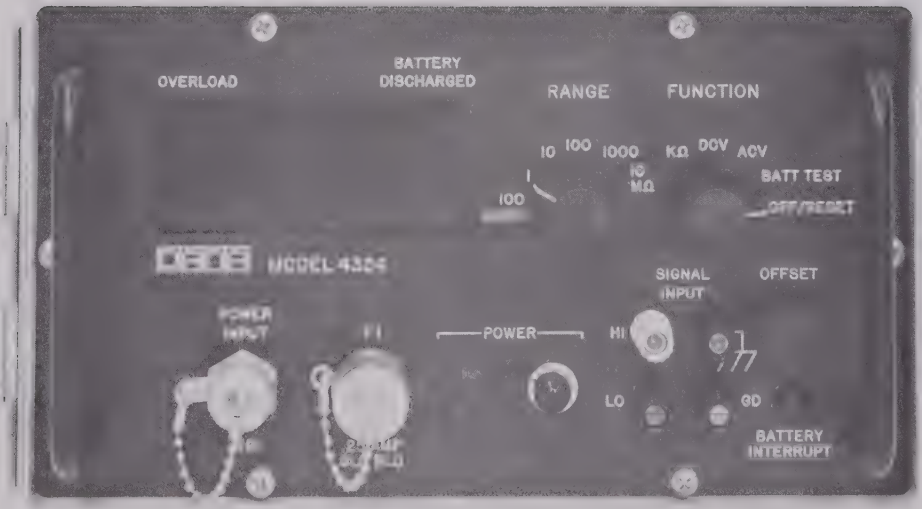

OVERLOAD
BATTERY DISCHARGED
RANGE
FUNCTION
10
100
1000
KΩ
DCV
ACV
1
100
10 MΩ
BATT TEST
OFF/RESET
MODEL 4324
SIGNAL INPUT
OFFSET
POWER INPUT
F1
POWER
HI
LO
GD
BATTERY INTERRUPT

SECTION 1 GENERAL DESCRIPTION

1.1 SCOPE.

1.2 This manual describes the Dana Model 4324 Digital Multimeter (figure 1.1). It is intended for use by those responsible for the operation, calibration, and repair of the instrument.

1.3 PURPOSE OF EQUIPMENT.

1.4 The Model 4324 Digital Multimeter (DMM) is a four-digit instrument with capability of measuring d-c voltage and resistance on five ranges and a-c voltage on four ranges. A fifth digit in the most-significant position provides 100% overrange on all functions. When equipped with the optional battery pack, the instrument is completely portable. Available functions and ranges are summarized in Table 1.1.

Table 1.1 - Instrument Capability

Range	DCV	ACV	KΩ
100 mV	X		
1	X	X	X
10	X	X	X
100	X	X	X
1000	X	X	X
10 MΩ			X

1.5 Housed in a rugged aluminum case, the instrument is compact and portable and tested to meet all environmental requirements of MIL-T-21200J-CLASS II. It is suitable for all bench, field, and flight line applications.

1.6 Light-emitting diodes (LED's) are utilized in the numerical display. An automatic intensity circuit adjusts the brightness of the display for prevailing light conditions and a blanking circuit removes all insignificant zeros on the readout. A unique set of cams on the FUNCTION and RANGE switches prevents the selection of "illegal" range-function combinations. Autopolarity circuits select and display polarity automatically.

1.7 BATTERY PACK.

1.8 With the battery pack, the instrument operates on power line voltage (115V or 230V) or on self-contained nickel cadmium batteries. The batteries provide eight hours of continuous operation and charge fully in 16 hours of line voltage operation.

1.9 A battery (BATT TEST) position on the FUNCTION switch allows the user to monitor the charge on the battery pack at any time. The reading obtained is easily converted to remaining discharge time (see Battery Operation, 2.10). When the battery discharges to 5.5 volts, the battery pack is automatically disabled to prevent overdrain and possible damage to the batteries. Recharging occurs whenever the instrument is operated on power line voltage.

1.10 MECHANICAL DESCRIPTION.

1.11 Case.

1.12 The front cover is side-hinged for access to the front (control) panel. The entire chassis is removed by loosening the front panel mounting screws and pulling the chassis forward. There is no electrical connection between the inner chassis and the protective case which also functions as a guard.

1.13 Front Panel.

1.14 Mounted on the front panel are the input terminals, operating controls, power input connector, line fuse, and readout panel.

1.15 Rear Panel.

1.16 On the rear panel is a line voltage switch that selects power transformer taps to accommodate either 115-volt or 230-volt line voltage. This switch is accessible by removing the threaded plug at the rear of the outer case.

1.17 Main Printed Circuit (PC) Board.

1.18 The main p-c board (or "motherboard") contains the power supply, all analog circuits, and all digital circuits except for the LED readout board.

1.19 Readout Board.

1.20 The readout board plugs into a connector on the main board directly behind the readout window. It contains the LED's and associated readout components.

1.21 ELECTRICAL DESCRIPTION.

1.22 The Model 4324 DMM uses the dual slope method of analog to digital conversion. In this method, the input signal is converted into a proportional current and integrated across a capacitor for a predetermined time period (50 ms), thereby establishing a voltage vs. time relationship. The capacitor is discharged at a linear rate by a fixed reference current generator. The time required for the capacitor to discharge is measured and displayed.

1.23 The majority of the digital circuitry is contained in a single counter/multiplexer integrated circuit (IC). This IC performs the counting, latching, multiplexing and blanking functions, as well as providing timing signals for the integration sequence. The analog portions of the instrument consist of integrated operational amplifiers and discrete components and are used for current conversion, signal conditioning (ac and resistance conversion) and integration functions.

1.24 SPECIFICATIONS.

1.25 Specifications are listed in Table 1.2. Test procedures for verification of specifications are given in Section 3.

Table 1.2 - Specifications

GENERAL	
Operating Voltage:	100 to 125V or 200 to 250V (switch selectable) 50 to 400 Hz
Maximum Power Requirement:	Operation while charging battery, 6 watts
Dimensions:	8.5 inches wide (216 mm) 3.5 inches high (89 mm) 11 inches long (279 mm)
Weight:	Without batteries 5.5 pounds (2.5 Kg) With batteries 7.5 pounds (3.4 Kg)
Battery:	Operating time 8 hours at 23°C Recharge time 16 hours at 23°C
Ranging:	Manual in all functions
Warm-up Time:	30 minutes to full accuracy

AC VOLTAGE	
Ranges:	1, 10, 100, 1000V rms
Overrange:	100% on all ranges (±1000V maximum input)
Resolution:	.01% of range (100 μV on 1V range)
Accuracy:	90 days, 25°C ± 5°C:
50 Hz to 10 kHz	±(.2% of reading +.05% of full scale)
10 kHz to 20 kHz	±(.5% of reading +.1% of full scale)
	6 months, 25°C ± 10°C:
50 Hz to 10 kHz	±(.2% of reading +.08% of full scale)
10 kHz to 20 kHz	±(.5% of reading +.1% of full scale)
Input Impedance:	1 megohm shunted by 200 pF
Overload:	1000V RMS or 500V DC on all ranges
Settling Time:	Less than three seconds to full accuracy

continued. . .

Table 1.2 - Specifications (Continued)

DC VOLTAGE	
Ranges:	±.1, ±1, ±10, ±100, ±1000V
Overrange:	100% on all ranges (±1000V maximum input)
Resolution:	.01% of range (10 μV on .1V range)
Accuracy:	90 days, 25°C ± 5°C: 1, 10, 100, 1000V ranges ±(.01% of reading +.01% of full scale) .1V range ±(.03% of reading +.03% of full scale)
	6 months, 25°C ± 5°C: 1, 10, 100, 1000V ranges ±(.01% of reading +.02% of full scale) .1V range ±(.03% of reading +.04% of full scale)
Polarity:	Automatic Bipolar
Temperature Coefficient:	1, 10, 100, 1000V range ±(.0015% of reading +.001% of full scale)/°C .1V range ±(.0015% of reading +.002% of full scale)/°C
Input Resistance:	.1 and 1V ranges 1000 Mohms Other ranges 10 Mohms
Normal Mode Noise Rejection:	Within .1% of line frequency 40 dB
Common Mode Noise Rejection: (1 KΩ imbalance)	Line operated 120 dB Battery operated Near infinite
Overload:	±1000V may be applied to any range without damage
Settling Time:	Zero to full scale – 1 second Full scale to zero – 1 second Out of overload – 5 seconds
Digitizing Time:	Less than 150 msec

continued. . .

Table 1.2 - Specifications (Continued)

RESISTANCE	
Ranges:	1K, 10K, 100K, 1M, 10M
Overrange:	100% on all ranges
Resolution:	.01% of range (.1 ohm on 1K range maximum)
Accuracy:	90 days, 25°C ± 5°C: 1, 10, 100 kilohm ranges ±(.02% of reading +.01% of full scale) 1 & 10 megohm ranges ±(.05% of reading +.01% of full scale)
	6 months, 25°C ± 5°C: 1, 10, 100 kilohm ranges ±(.02% of reading +.02% of full scale) 1 & 10 megohm ranges ±(.07% of reading +.02% of full scale)
Current Through Unknown:	100 μA maximum
Response Time:	1K - 100K 1 second to rated accuracy 1M 5 seconds 10M 10 seconds
Overload:	250V DC or RMS AC on all ranges without damage

ENVIRONMENTAL	
Operating Temperature:	With batteries –40°C to +40°C (Charging) –40°C to +60°C (Discharging) Without batteries –40°C to +55°C (Intermittent operation to 71°C)
Storage Temperature:	–62°C to +85°C (–40°C to +50°C with battery option installed)

continued. . .

Table 1.2 - Specifications (Continued)

Humidity:	100% with condensation in the way of frost or liquid water on the equipment. Withstands this humidity during operation, intermittent operations, and exposure in a non-operating condition.
Altitude:	Operating 10,000 ft. Non-operating 50,000 ft.
Vibration:	Continuous resonant free vibration along each of the three mutually perpendicular axes within the following frequency ranges and amplitudes: Frequency — Double Amplitude 5-15 Hz — 0.06 inch 15-25 Hz — 0.04 inch 25-55 Hz — 0.02 inch
Shock:	Eighteen impact shocks of 20g, consisting of three shocks in opposite directions along each of three perpendicular axes. Each shock impulse having a time duration of 11 ± 1 milliseconds. The g value to be within ±10% when measured with a 0.2 to 250 Hz filter, and the maximum g shall occur at approximately 5½ milliseconds.
Electromagnetic Interface:	Meets MIL-STD 461 when tested in accordance with MIL-STD 462 as required by paragraph 3.2.10 of MIL-T-21200J.
Sand & Dust:	Will withstand exposure to sand and dust particles as encountered in operational areas of the world per paragraph 3.2.19.6 of MIL-T-21200J.
Salt Atmosphere:	Will withstand exposure to a salt atmosphere per paragraph 3.2.19.7 of MIL-T-21200J.
Explosive Conditions:	Will not cause ignition of an ambient explosive gaseous mixture with air when operating in such an atmosphere.
Drop Test: (combination case)	No evidence of physical damage or malfunction after 14 drops each corner and face from 30" height.

The Dana Model 4324 is designed to comply with all other environmental requirements of MIL-T-21200J.

(All specifications are subject to change at manufacturer's discretion.)

2.1 UNPACKING AND INSPECTION.

2.2. The Model 4324 is secured in its shipping carton by plastic foam packing material. This material holds the instrument firmly in its carton and absorbs any reasonable shock normally encountered in transit. Prior to unpacking, examine the exterior of the shipping carton for any signs of damage. Carefully remove the instrument from the carton and inspect its exterior for any signs of damage. If damage is found, notify the carrier immediately.

2.3 Included with the instrument are the instruction manual and power cord. The power cord is stored within the hinged front cover of the instrument. The front cover is opened by unfastening the latches on the right side of the case. The cover can be removed entirely by merely lifting the cover off of the hinges.

2.4 BATTERY PACK.

2.5 The optional battery pack is factory-installed when ordered with the instrument. For field installation, perform the procedure in Section 5, paragraph 5.6.

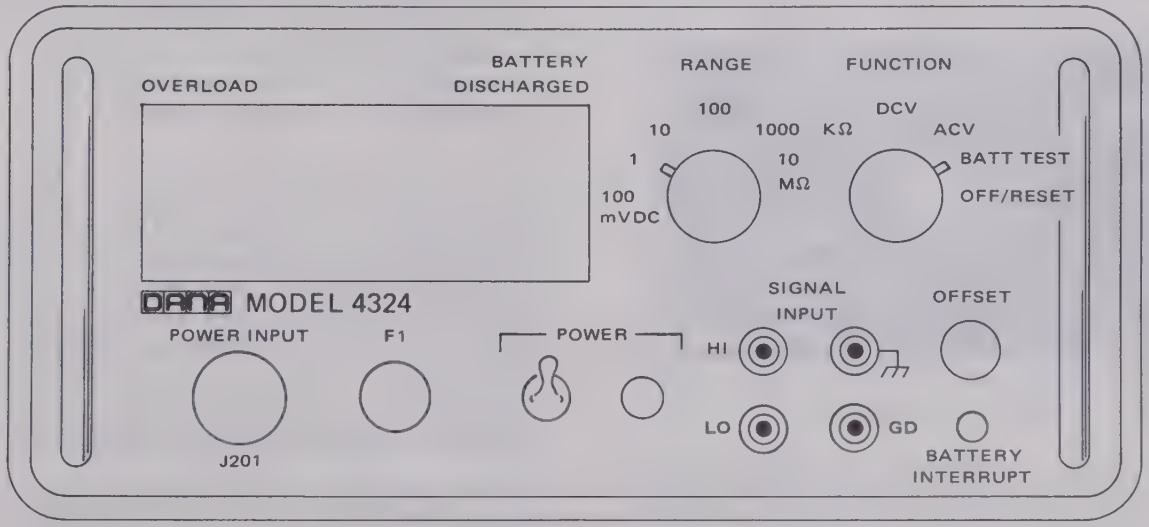


Figure 2.1 - Controls and Indicators

2.6 AC POWER REQUIREMENTS.

2.7 The Model 4324 operates on line voltages of either 115V (100 to 125V) or 230V (200 to 250V), 50 to 400 Hz. Maximum power requirement is 6 watts.

2.8 A power cable having a three-pin type plug is supplied with the instrument. It connects to power connector J201 on the front panel (figure 2.1). The power line voltage selector switch is accessible upon removal of a threaded plug on the rear of the outer case (figure 2.2). The instrument is shipped with the switch in the 115 volt position (slide switch to the left). For operation on 230 volts, remove plug and insert a small screwdriver through the opening and slide the switch to the 230 volt position (slide switch to right).

Figure 2.2 - Rear Panel

2.9 A fuseholder on the front panel contains the line fuse F1. This is a .25 amp fuse for both 115 volt operation and 230 volt operation.

2.10 BATTERY OPERATION.

2.11 The manufacturer's rating of battery life is approximately 200 charge-discharge cycles. However, this can vary greatly depending on the number of complete discharges and the number of partial discharges involved. Generally, a cell which has been consistantly discharged to only one-half of its capacity will supply less energy on subsequent discharges than another cell that has been fully discharged. Allowing the batteries to discharge fully will usually result in more predictable performance.

> **NOTE**
>
> Dana buys the best batteries obtainable from battery manufacturers and each unit is tested before installation in the DMM. However, due to inherent variance between individual cells and unpredictability of charge-discharge patterns, batteries are specifically excluded from the Dana parts warranty.

2.12 Battery voltage can be checked at any time by setting the FUNCTION switch to BATT TEST position. The decimal point is of no significance in this mode. For example, a reading of 62.0 indicates 6.20 volts. The battery automatically disconnects at 5.5V. It can be restarted, if plugged into line voltage, by turning the FUNCTION switch to OFF/RESET (to trigger start-up circuit), then back to a function position. Discharged batteries will restart the instrument long enough for a battery test reading.

2.13 The approximate discharge time remaining can be estimated by use of the graph shown in figure 2.3. The

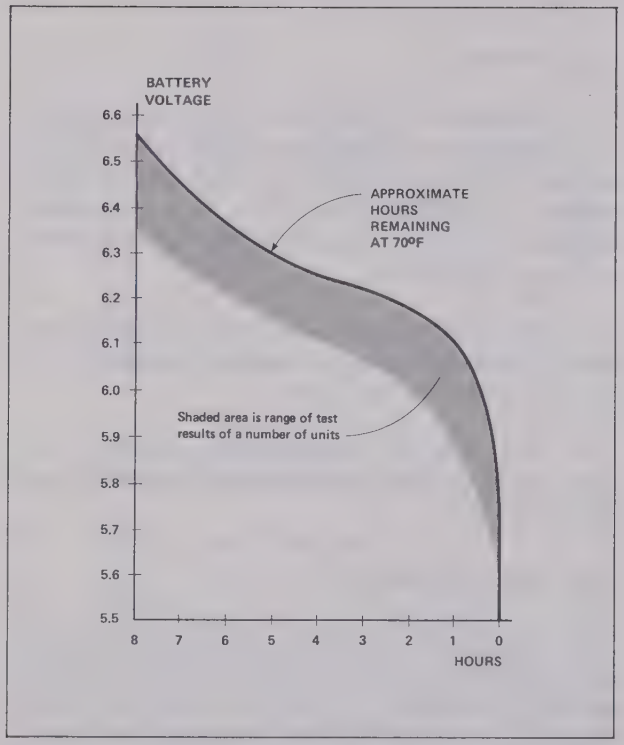


Figure 2.3 - Remaining Discharge Time

graph was prepared from results of tests of a number of units. The shaded area around the curve indicates the range of test results while the curve itself represents minimum time remaining. Therefore, a reading of 5.95 volts indicates a range of 1/4 to 1-1/2 hours discharge time remaining, depending on the particular set of batteries.

2.14 Battery charge occurs whenever the instrument is operated on power line voltage. With the instrument turned off, but still connected to the line, charging occurs at a higher rate.

Table 2.1 - Function Switch

OFF/ RESET	This position removes power to the measurement portion of the instrument. With instruments equipped with the battery pack, the battery charging circuitry continues to operate when the instrument is connected to the power line. It is necessary to turn the FUNCTION switch to this position after the front cover has been removed to reset (turn on) the battery voltage.
BATT TEST	This position permits the monitoring of battery pack voltage (on instruments equipped with the battery pack). See paragraph 2.12.
ACV	This position selects the measurement of AC volts on the 1, 10, 100, and 1000 volt ranges.
DCV	This position selects the measurement of ± DC volts on the .1, 1, 10, 100, and 1000 volt ranges.
KΩ	This position selects the measurement of resistance with full-scale ranges of 1, 10, and 100 Kilohms and 1 and 10 megohms.

2.15 CONTROLS AND INDICATORS (Figure 2.1).

2.16 Function Switch.

2.17 The FUNCTION switch is a five-position rotary switch that is cam-interlocked with the RANGE switch. This feature prevents the selection of an improper function/range combination. The FUNCTION switch selects power off, battery check or any of the three measurement functions (see Table 2.1).

2.18 Range Switch.

2.19 Range is selected by means of the six-position rotary RANGE switch. Function/range combinations and decimal positions are shown in Table 2.2.

2.20 Offset Control.

2.21 OFFSET is a control by which the user can zero the instrument. With the instrument on the 100 mV range and the input terminals shorted, OFFSET is adjusted for a display of zero (0.00) on the readout.

Table 2.2 - Available Ranges

Function			Range	Decimal Position
Ω	AC	DC		
		X	100 mV	000.00
X	X	X	1	0.0000
X	X	X	10	00.000
X	X	X	100	000.00
X	X	X	1000	0000.0
X			10 MΩ	00.000

2.22 Display.

2.23 The numerical readout consists of four seven-segment LED (light-emitting diodes) alpha-numeric devices and one numeral 1/polarity symbol device. The intensity of the readout is automatically controlled. It is at maximum brightness in high ambient light and at a lower brightness level in low ambient light.

2.24 Non-significant zeros are blanked to simplify readings. In an overload condition, all digits are blanked and the OVERLOAD indicator lights.

2.25 The BATTERY DISCHARGED indicator lights whenever the battery voltage drops below the allowable level of 5.5 volts.

2.26 Battery Interrupt.

2.27 BATTERY INTERRUPT is an interlock switch that turns off battery voltage when the front cover of the instrument is installed. Its purpose is to prevent accidental discharging of the batteries while the instrument is unused. When the front cover is removed, the FUNCTION switch must be turned to OFF/RESET (to trigger the start-up circuit), then back to the desired function before the instrument will operate.

2.28 Power Switch.

2.29 The POWER switch is a toggle switch located on the front panel of the instrument. When set to the up position it applies power to the instrument.

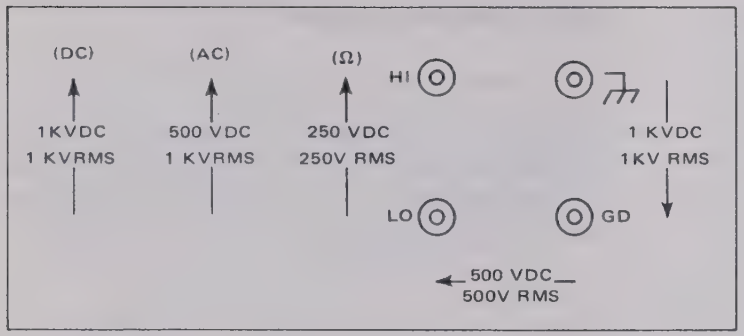


Figure 2.4 - Signal Input Terminal (Maximum Input)

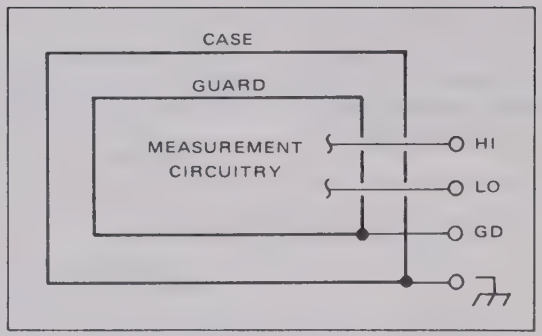


Figure 2.5 - Signal Terminal Connections

2.30 OPERATING PROCEDURE

2.31 Signal Input Terminals

2.32 The signal input terminals are located on the front panel and consist of four 5-way binding posts. The terminals, shown in figure 2.4, are the high input (HI), the low input (LO), the guard box (GD) and the instrument case (⏚). Maximum allowable voltage between the terminals is indicated in the figure. The HI and LO inputs are used for all voltage and ohms measurements; the guard input is for noise shielding and the case connector is used for R.F. shielding. Figure 2.5 illustrates how the input and shields are connected within the instrument.

2.33 Input Cables

2.34 For guard usage, the input test leads available for the instrument are used (Option 01, Dana Part No. 403869). For high noise environments, shielded cables are suggested. Two suitable arrangements are illustrated in figure 2.6 and 2.7.

2.35 Voltage Measurements

2.36 For ac and dc voltage measurements, the lead from the LO terminal is connected to the signal source of the potential nearest ground; conversely the lead from the

HI terminal is connected to the signal source at the potential away from ground. For improved noise rejection, GD is connected to LO. In high noise environments, a two conductor shielded input cable as shown in figure 2.6 may be required.

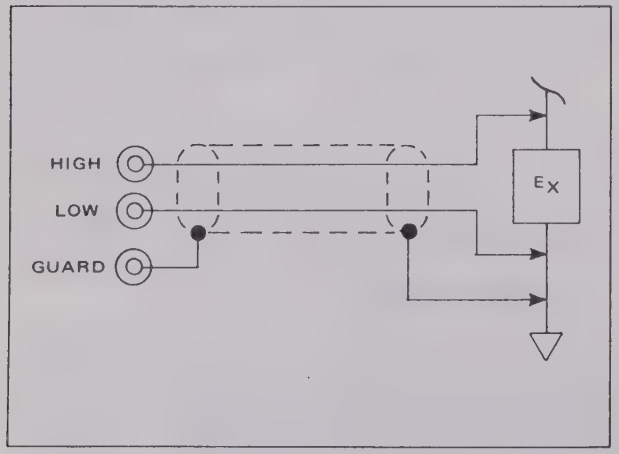


Figure 2.6 - Voltage Measurement Connections

2.37 Ohms Measurements

2.38 Measurements to determine the resistance of a component are made in the same manner as for measuring volts except that power to the equipment being measured must be removed. For high noise environments, the same rules apply. An example of a partially shielded input for ohms measurement is shown in figure 2.7.

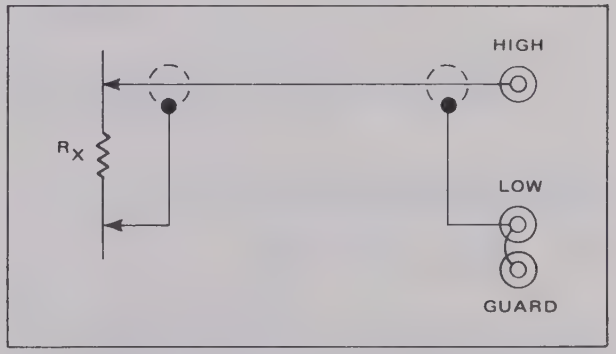


Figure 2.7 - Ohms Measurement Connections

SECTION 3 SPECIFICATION TESTS

3.1 GENERAL.

3.2 This procedure is designed to ensure that the instrument is operating properly and within its specifications. If any of the readings are not within tolerance refer to the calibration procedure. If the instrument fails to operate properly, refer to the troubleshooting procedure.

3.3 PREPARATION.

3.4 The DMM requires thirty minutes warmup time. Pre-zero the instrument prior to each accuracy check by selecting DCV, 100 mV range, connecting a jumper across the HIGH and LOW input terminals and adjusting the front panel zero control for a display reading of 0000.

3.5 EQUIPMENT.

3.6 A list of required equipment is given in Table 3.1.

3.7 PROCEDURE.

3.8 Connect the DMM and the test equipment as shown in the figure supplied with each accuracy check. Select the controls and input as called out in the tables and monitor the DMM readout for the indicated values.

Table	Title
3.1	Required Equipment
3.2	DC Test
3.3	AC Test
3.4	KΩ/MΩ Test
3.5	Common Mode Noise Rejection Test
3.6	Normal Mode Noise Rejection Test

Table 3.1 - Required Equipment

TYPE	REQUIRED SPECS	SUGGESTED EQUIPMENT
DC Voltage Standard	Adjustable: 0 – 1000V Resolution: 1 μV on 10V range Accuracy: ± .003%	Cohu Model 351
AC Laboratory power source	Variable: 0 to 500V RMS & 20 Hz to 100 KHz. Resolution better than 100 PPM. Harmonic distortion of 0.1% or less. Stability of .01%.	Optimation Type AC 110 (oscillator, matching transformer & power amplifier)
Thermal Transfer voltmeter	AC/DC thermal transfer voltmeter. Ranges: 1 to 500V. Accuracy 0.05% or better.	Holt Model 6 Thermal Transfer Voltmeter
Standard Resistors	1K, 10K, 100K, and 1, 10, and 100 Megohm. All ± .005% except 10 Meg & 100 Meg which are ± .01%.	ESI SR-1 series standard resistors.
1/2W Carbon Resistor	1,000 ohms ± 10%	
1/2W Carbon Resistor	10,000 ohms ± 10%	
Capacitor	1 μF, 100V or more	
Batteries, 2 required	1.5V cells having screw type binding posts.	

Table 3.2 - DC Test

DMM		INPUT SIGNAL		NOMINAL READING	TOLERANCE	
FUNCTION	RANGE	DC VOLTS				
DC	+100 mV	+.100000		+100.00	93.93 to 100.07	
	+1V	+1.000000		+1.0000	.9997 to 1.0003	
	+10V	+10.00000		+10.000	9.997 to 10.003	
	+100V	+100.0000		+100.00	99.97 to 100.03	
	+1000V	+1000.000		+1000.0	999.7 to 1000.3	
	−1V	−1.000000		−1.0000	.9997 to 1.0003	

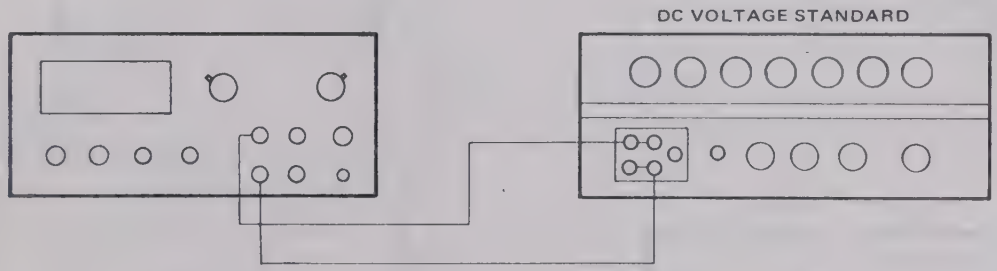


Table 3.3 - AC Test

DMM		INPUT SIGNAL		NOMINAL READING	TOLERANCE	NOTE
FUNCTION	RANGE	AC STANDARD				
AC	1	1.00000	400 Hz	1.0000	.9972 to 1.0028	23°C ± 5°C
	1	1.00000	15 KHz	1.0000	.9940 to 1.0060	
	10	10.0000	400 Hz	10.000	9.972 to 10.028	
	10	10.0000	15 KHz	10.000	9.940 to 1.0060	
	100	100.000	400 Hz	100.00	99.72 to 100.28	
	1000	1000.00	400 Hz	1000.0	997.2 to 1002.8	

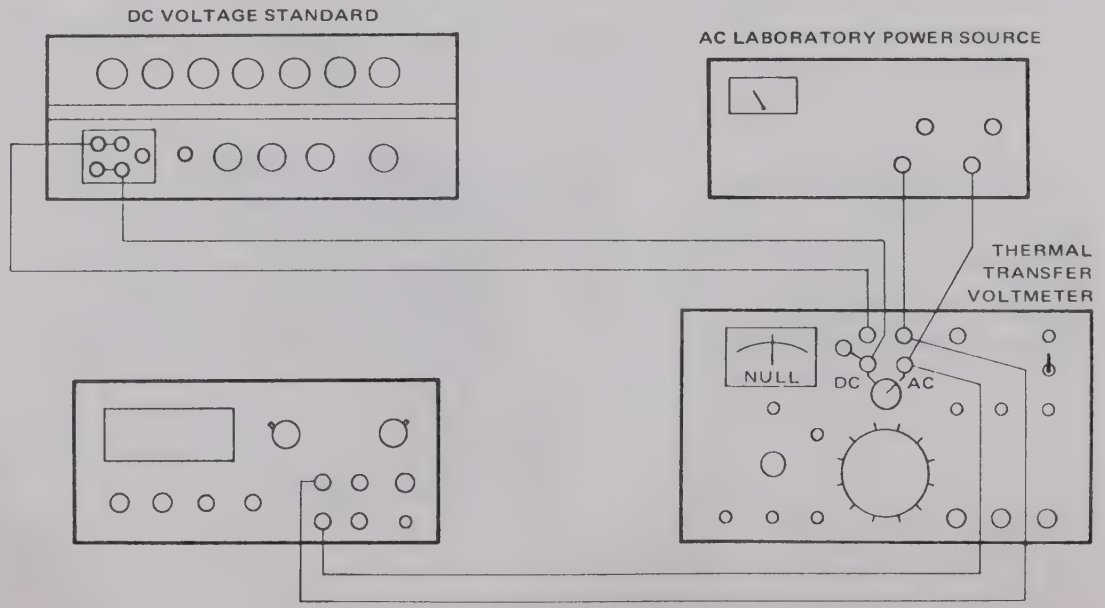


Table 3.4 - KΩ/MΩ Test

DMM		INPUT SIGNAL		NOMINAL READING	TOLERANCE	NOTE
FUNCTION	RANGE	OHMS STANDARD				
KΩ	1	1 KΩ		1.0000	.9996 to 1.0004	23°C ± 5°C
	10	10 KΩ		10.000	9.996 to 10.004	
	100	100 KΩ		100.00	99.96 to 100.04	
	1000	1 MΩ		1000.0	999.1 to 1000.9	
	10 MΩ	10 MΩ		10.000	99.91 to 100.09	

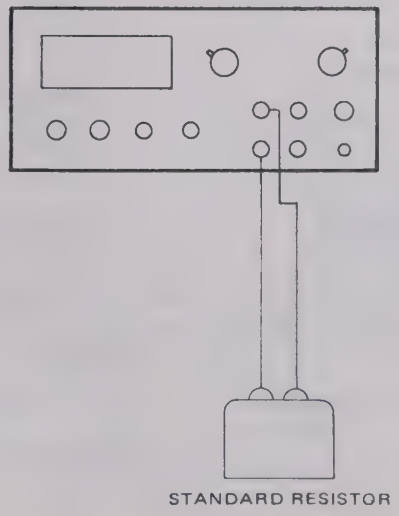


Table 3.5 - Common Mode Noise Rejection Test

DMM		INPUT SIGNAL		NOMINAL READING SEE NOTE 1	TOLERANCE	NOTE
FUNCTION	RANGE	S-1				
DCV	10	GND				1) With switch S-1 in the off position, record the reading displayed in the DMM readout in the NOMINAL READING column. Set S-1 to the AC position for common mode check.
		AC			±1 digit	

NOTE: THE TWO BACK TO BACK 1.5V BATTERIES PROVIDE A SMALL INPUT SIGNAL OF SEVERAL MILLIVOLTS TO OFFSET THE READING FROM ZERO (SINCE NO TWO SUCH BATTERIES ARE EQUAL IN VOLTAGE). THIS AVOIDS POLARITY CHANGES DURING CMR TESTS WHICH MAY MAKE THE READING HARD TO INTERPRET.

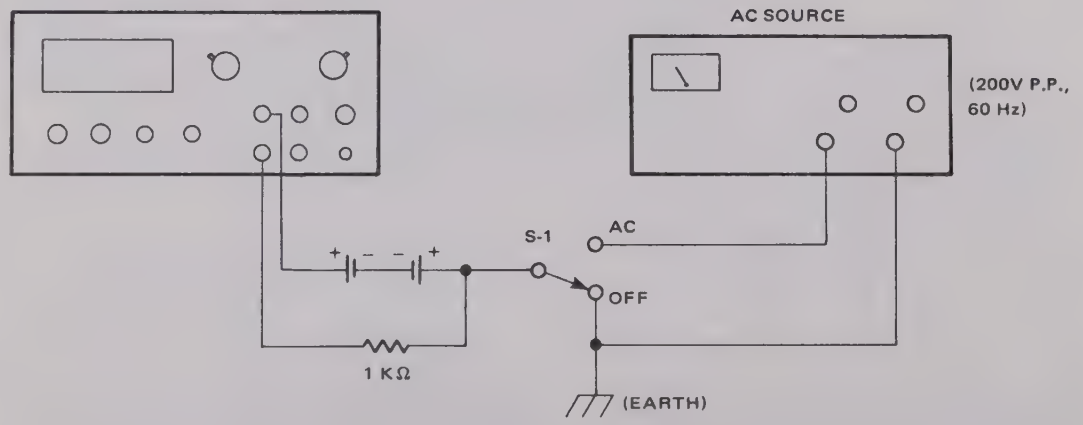
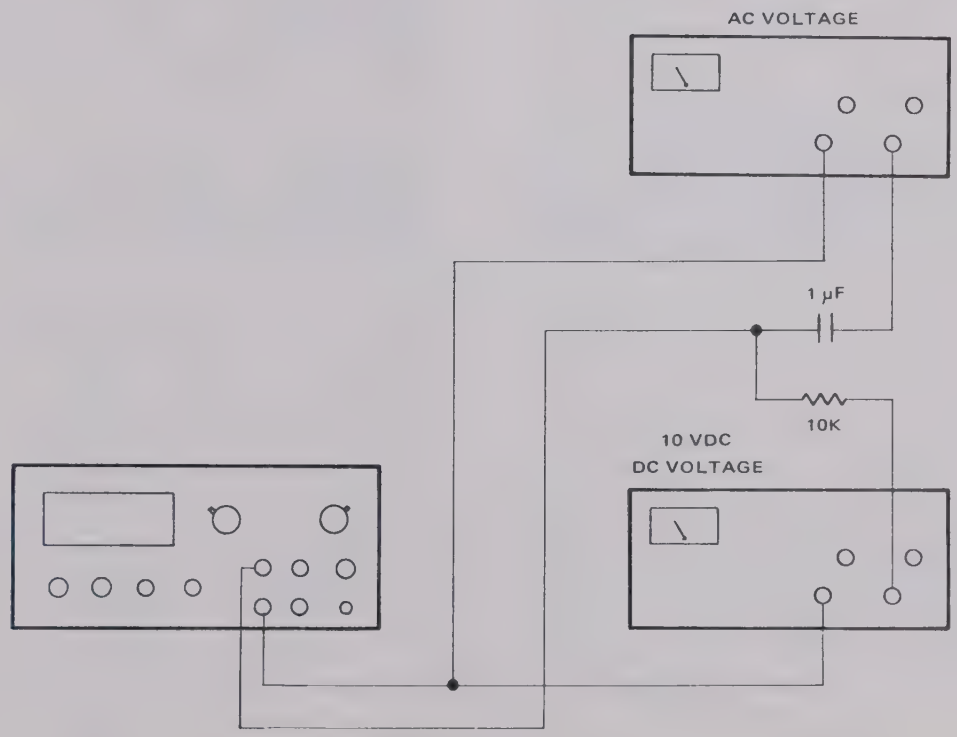


Table 3.6 - Normal Mode Noise Rejection Test

DMM		INPUT SIGNAL		NOMINAL READING	TOLERANCE	
FUNCTION	RANGE	DC	AC			
DC	10	10V	200 mV P.P. 60 Hz	10.000	±1 digit	



4.1 GENERAL.

4.2 This section describes the operation of the Model 4324 DMM and includes the basic technique used as well as a more detailed explanation of the major functional portions shown in figures 4.2 and 4.11. The drawings contained in this section are included to aid in the description and to supplement the schematics of Section 6.

4.3 The instrument uses the dual slope integration method for analog to digital conversion. As illustrated in figure 4.1, the input signal is converted to a proportional, positive current (I_S) for a set time period (T_0 to T_1). During this time period a voltage is developed across the integration capacitor (C), the value of which is dependent on I_S. A fixed value of negative current (I_R) is then applied to the capacitor. The time required to discharge the voltage across the capacitor (T_1 to T_2) is measured and displayed.

4.4 CIRCUIT DESCRIPTIONS.

4.5 The attenuator, AC converter and Ohms converter perform the signal conditioning function; the G_m converter and digitizer provide the analog to digital conversion. These circuits and the display circuits are shown simplified in figure 4.2. The power supply including the optional battery pack is shown in figure 4.11.

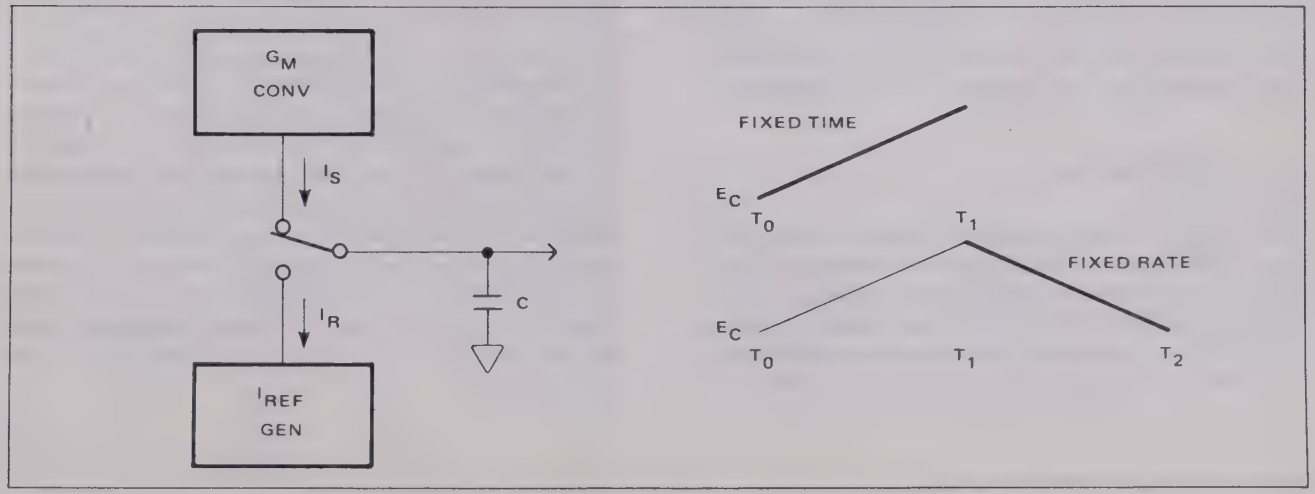


Figure 4.1 - Dual Slope Sequence

4.6 Signal Conditioning.

4.7 ATTENUATOR

4.8 The attenuator, controlled by the RANGE switch (S1), reduces the level of the input signal to a value acceptable to the measurement circuits. The DCV attenuator consists of series-connected resistors, forming a voltage divider. For measurements on the 10, 100, and 1000 volt ranges, the attenuator reduces full scale inputs to a level of ± 1 volt. No attenuation of the input signal takes place on the 100 millivolt and 1 volt ranges. For ACV measurements, the attenuator is a feedback network for the AC converter. The negative feedback supplied by the attenuator limits the dc output of the AC converter to −1 volt for full scale inputs on all ACV ranges. For kilohms measurements, a tapped resistor string (used as a voltage divider in DCV measurements) is used in conjunction with the ohms reference to produce a fixed current for each ohms range.

4.9 AC CONVERTER.

4.10 The AC converter generates a negative output level proportional to the ac input signal and consists of diodes CR1 and CR2, driven by a high output impedance amplifier (Q7, Q8, and Q9). The ac signal flows through amplifier Q5/M1 of the G_m converter which inverts and amplifies the signal, through the converter amplifier and diodes CR1 and CR2. The current flows through each diode alternately dependent on the polarity of the signal and recombines as an ac signal across resistor R19 of the ac attenuator. This ac signal is fed to a summing node at the input of Q5/M1 and determines the gain of the network. The negative portion of the ac current flowing through diode CR2 develops a negative half wave voltage across resistors R20 and R21. The half wave signal is filtered and fed to the G_m converter for measurement.

4.11 OHMS CONVERTER.

4.12 The ohms converter consists of a voltage source supply −1 volt for 10 megohms measurements and −10 volts for measurements on all other ohms ranges. The voltages are taken from M5 and M4 driven by the same precise current source from which the reference current is derived (see figure 4.4). The voltage is fed through a resistive current divider producing a negative current (the value of which is dependent on the range selected) and flows to a summing node at the inverting input of amplifier M1. The output of Q5/M1, connected to the LOW input connector, goes positive causing a positive current to flow through the resistor being measured, connected across the input terminals. The current flows through the HIGH input connector to the summing node and the circuit stabilizes when the positive and negative currents are equal. The voltage developed across the unknown resistor is then measured by the remainder of the circuitry.

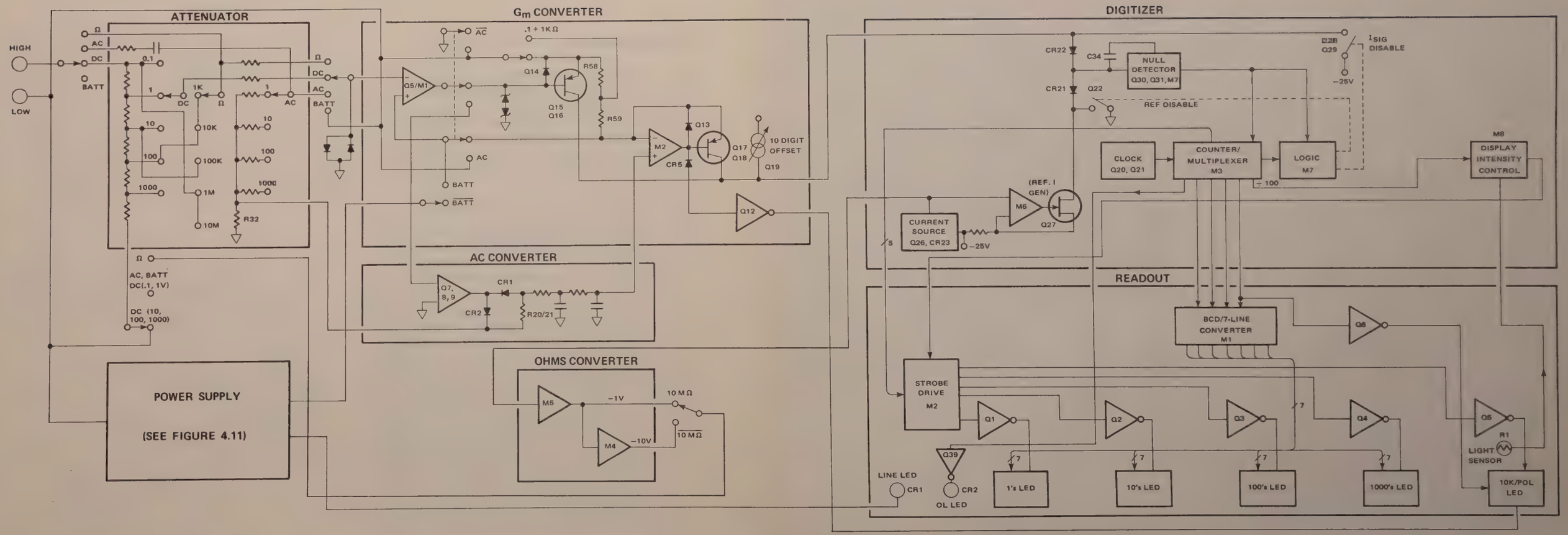


Figure 4.2 - Block Diagram, Model 4324

4.13 G_m Converter.

4.14 The G_m converter converts an incoming ± DC level into a proportional, positive, DC current (I_S). The current is subsequently routed to the integrator during the SIG INT part of the measurement cycle. The converter also supplies a fixed, positive offset current to compensate for a 10 count delay generated by the counter (see paragraph 4.30).

4.15 The G_m converter is shown simplified in figure 4.3 and consists of two polarity sensitive voltage-to-current converters and a fixed value current generator. Each converter consists of an operational amplifier (one with dual FET input) and two Darlington-connected transistors; for simplicity, the transistor pairs and the dual FET, operational amplifier combination are shown as single units. With positive inputs, the converter operates as shown in figure 4.3a. A positive potential applied across the input of the circuit causes the output of Q5/M1 to go negative and transistor Q15/Q16 to conduct, the circuit stabilizes when the voltage across resistors R58 and R50 (2 KΩ) is equal to the input potential. The current through transistor Q15/Q16 (I_S) is determined by $E_{in}/2K$. A full scale input (1 volt) therefore generates 0.5 mA. For measurements on the 1 Kilohm and 100 mV ranges, the full scale input is 0.1 volt. In these cases, the RANGE switch (S_I) is set to the 200Ω position and I_S is equal to $E_{in}/200\Omega$.

4.16 For negative inputs (figure 4.3b), the output of M1 goes positive causing current to flow through diode Q14; the circuit stabilizes when the potential across R58 and R59 equals the input potential. The current through the resistors flows into the summing node of M2 causing the output of M2 to go negative and forward biasing Q17/Q18. The M2,

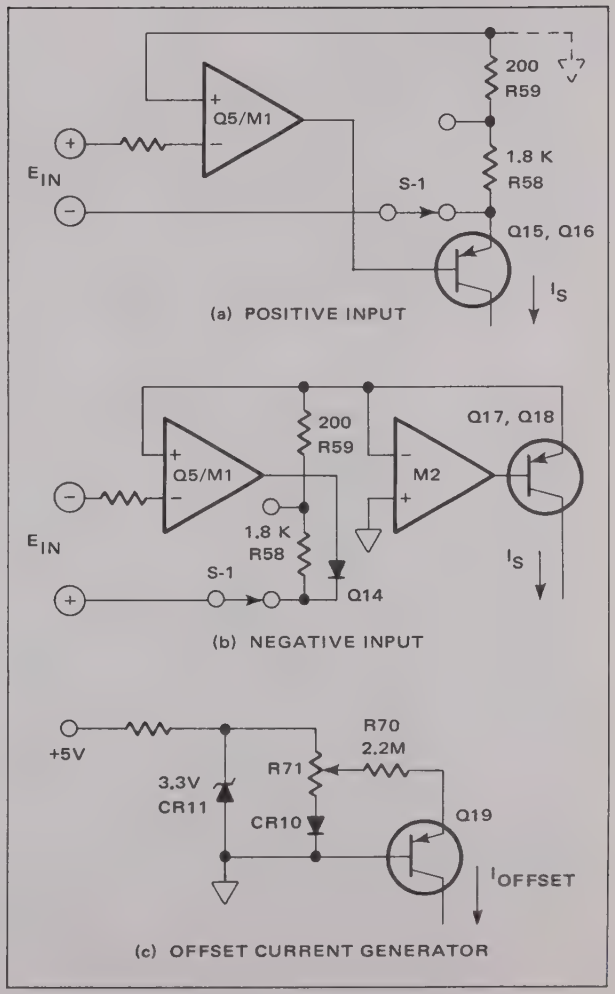


Figure 4.3 - G_m Converter

Q17/Q18 circuitry stabilizes when the current through Q17/Q18 is equal to the current through resistors R58 and R59. The increase in current required for 0.1 volt full scale inputs is derived in the same manner as for positive inputs.

4.17 The offset generator, shown in figure 4.3c, produces a fixed 0.5 μamps of current. Zener diode CR11 provides a stable 3.3 volts across potentiometer R71 and forward biases diode CR10. The current through Q19 is dependent on the voltage across R70. Temperature compensation for the generator is provided by CR10.

4.18 Digitizer.

4.19 REFERENCE GENERATOR.

4.20 The reference generator provides a precise negative reference current used during the reference integration period and the two ohms reference voltages, −1 and −10 volts.

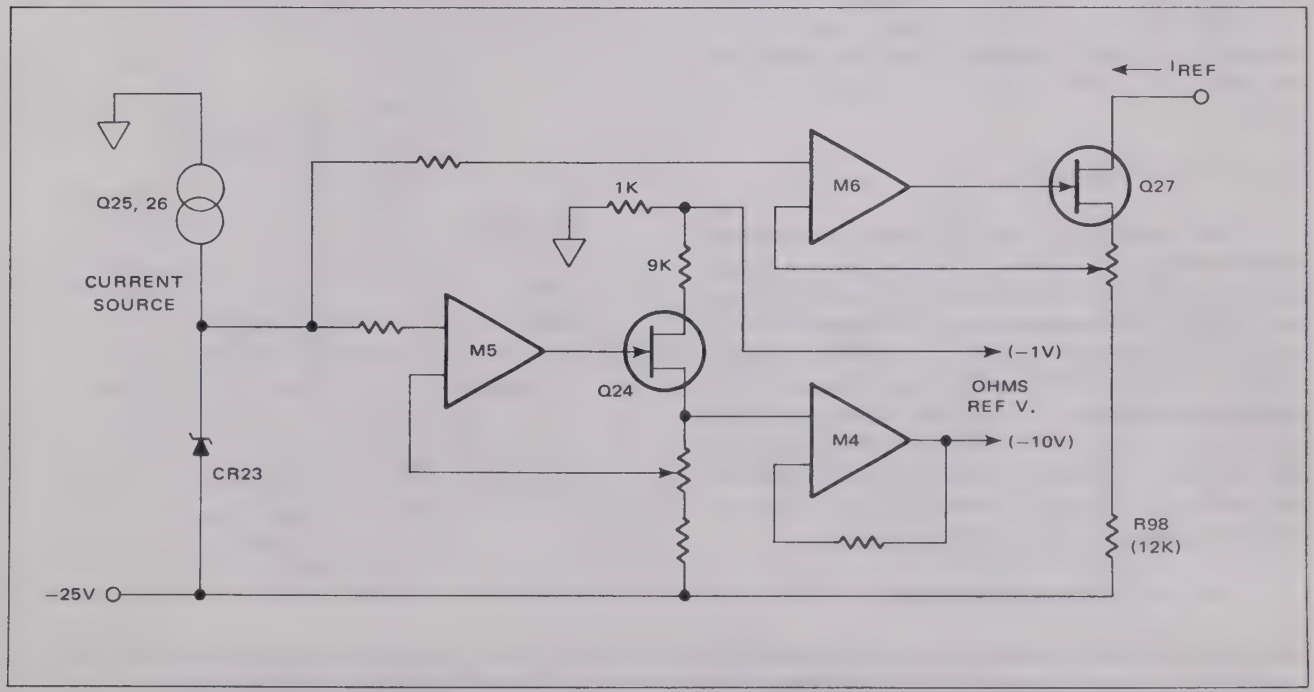


Figure 4.4 - Reference Current Generator

4.21 The current source consists of zener diode CR23 (approximately 6 volts), transistors Q25 and Q26, and associated components. Amplifier M6 is interconnected with FET Q27 and adjusted to provide a constant 6 volts across R98. This circuit draws a fixed and stable 0.5 milliamps of current (I_R) from the integrating capacitor during the reference integration period.

4.22 Amplifier M5 and FET Q24 are set to provide −10 volts at Q24. This is the −10 volt reference voltage used for ohms measurement on all of the lower ranges. It is buffered by amplifier M4. The −1 volt reference is used only for measurement on the 10 megohm range and requires no buffering. It is taken directly from a voltage divider to ground.

4.23 NULL DETECTOR.

4.24 The null detector (figure 4.5) monitors the voltage across the integrating capacitor (C34) and generates a logic false signal when the voltage drops below a predetermined level. The null detector consists of an N-channel FET Q31, transistor Q30 and two stages of AND gate M7. A voltage divider consisting of R102 and R105 and filtered by C35, provides approximately −13 volts for the source of Q31 and one side of capacitor C34. Resistor R101 increases the gain and speed of the null detector by supplying positive feedback to the M7 input. Diode CR18 prevents the M7 input from going more negative then 0.7 volts.

4.25 SWITCH LOGIC/INTEGRATOR.

4.26 The switch logic shown in figure 4.6 controls the flow of the currents from the G_m converter (I_S) and reference current generator (I_R) to integrator capacitor C34. During the signal integration period, the QE_1 and QE_2 outputs from the counter/multiplexer (M3) are both true causing M7-6 to be false. M7-8 is true, causing Q22 to turn on. This supplies the current to the reference current

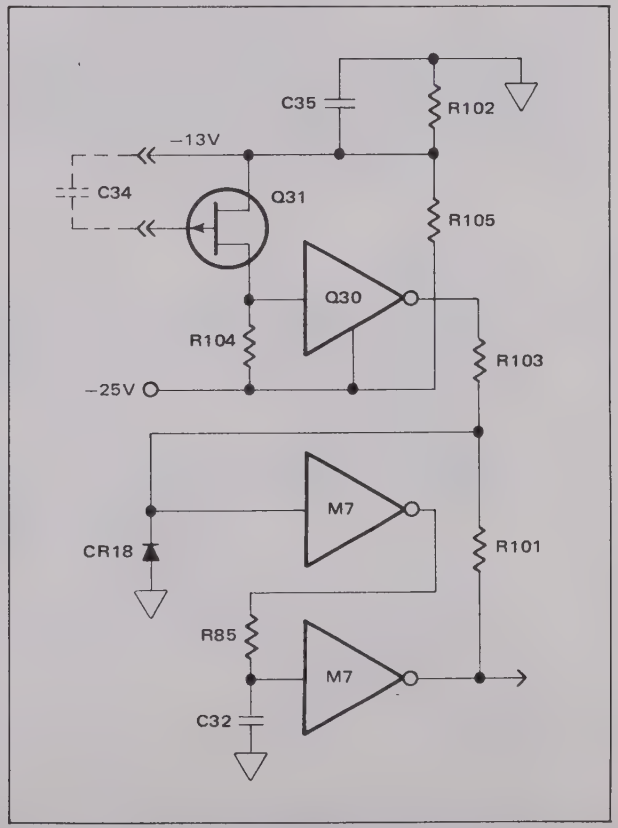


Figure 4.5 - Null Detector

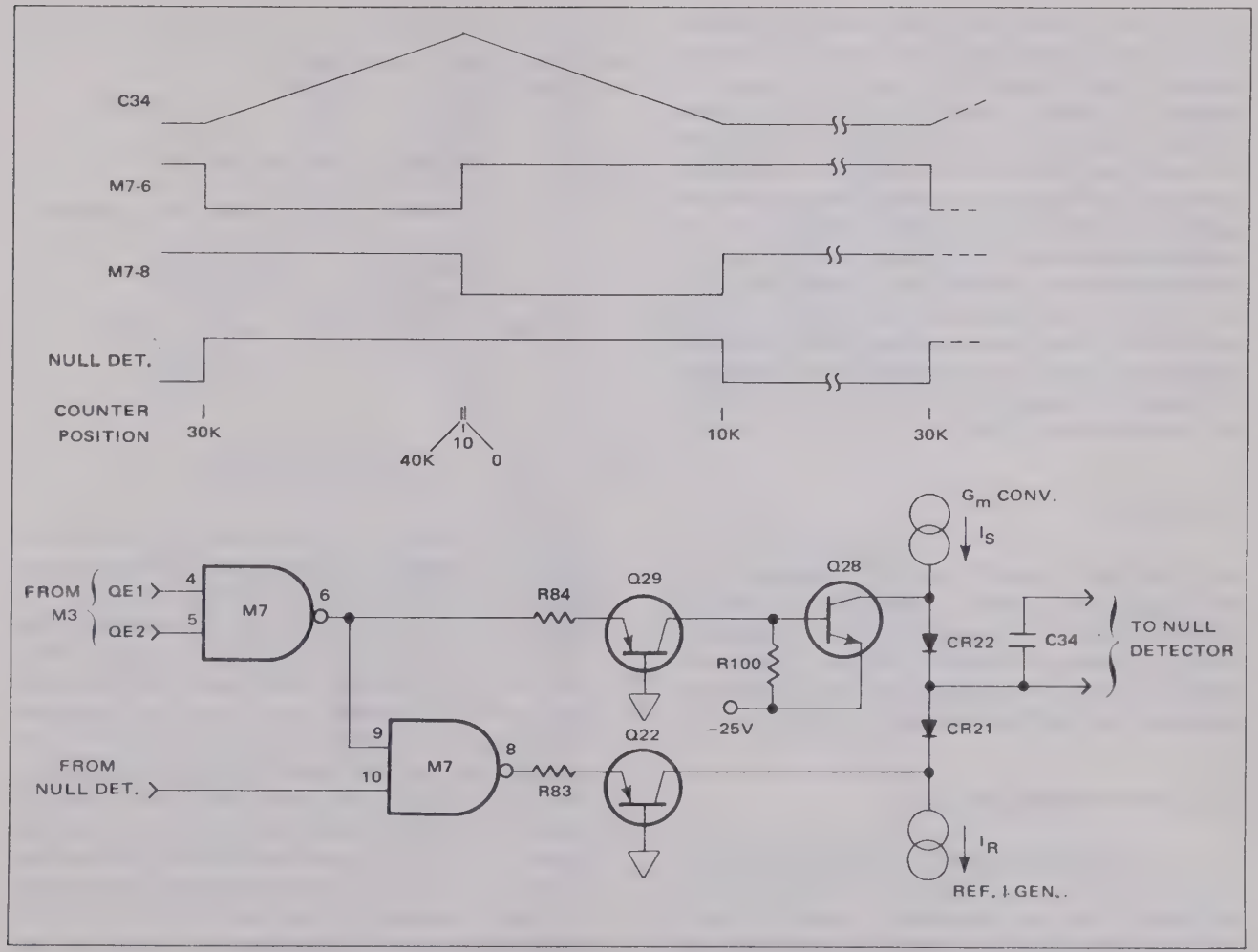


Figure 4.6 - Switch Logic/Integrator (Full Scale Input)

generator and back-biases CR21. With M7-6 false, transistors Q29 and Q28 are biased off and the current from the G_m converter flows through CR22 into C34, causing the capacitor to charge at a linear rate. At the completion of the signal integration period, QE_1 and QE_2 go false and M7-6 goes true. Transistors Q29 and Q28 are biased on, drawing all of the current from the G_m converter and back-biasing diode CR22. With the positive charge on C34, the null detector output to M7-10 is true and, with M7-6 true, sets M7-8 false which turns Q22 off. Current from C34 is now drawn by the reference current generator through diode CR21. When the voltage across C34 drops to its premeasurement level, the null detector output goes false, M7-8 goes true turning transistor Q22 back on, and no current flows into or out of C34.

4.27 CLOCK.

4.28 The clock, shown in figure 4.7, generates a 200 kHz signal used to drive the counter of the counter/multiplexer (M3). The counter is a free running multivibrator consisting of transistors Q20 and Q21. Diodes CR25 and CR26 and capacitor C26 insure start up by deriving the base bias from the collector outputs.

4.29 COUNTER/MULTIPLEXER.

4.30 The counter/multiplexer (integrated circuit M2) is shown in the boxed area of figure 4.8. The unit, with inputs from the clock and null detector, generates the switch logic data (QE_1 and QE_2) as well as the multiplexed data for the display portion of the instrument.

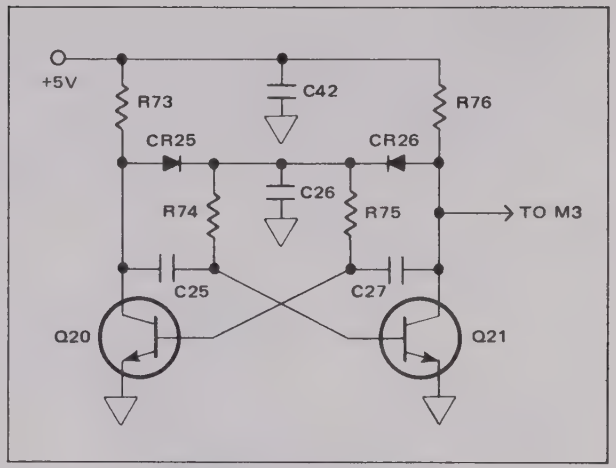


Figure 4.7 - Clock

4.31 The counter, consisting of four divide-by-ten counters, a divide-by-four counter and a ten-count pause circuit, runs continuously from the 200 kHz clock. The BCD outputs of the counters (A, B, C, D, and E) drive five four-bit latches which store the data at the end of a measurement cycle. When the counter reaches 30,000, outputs QE_1 and QE_2 are both true and the signal integration period begins. At 40,000, outputs QE_1 and QE_2 go false marking the end of the signal integration period and the start of the reference integration period. The counter advances for ten more clock cycles (due to the ten-count pause circuit) and then overflows to 00000. The ten-count pause circuit operates in conjunction with the ten-digit offset current generator of the G_m converter to prevent switching transients from prematurely firing the null detector for inputs at or near zero.

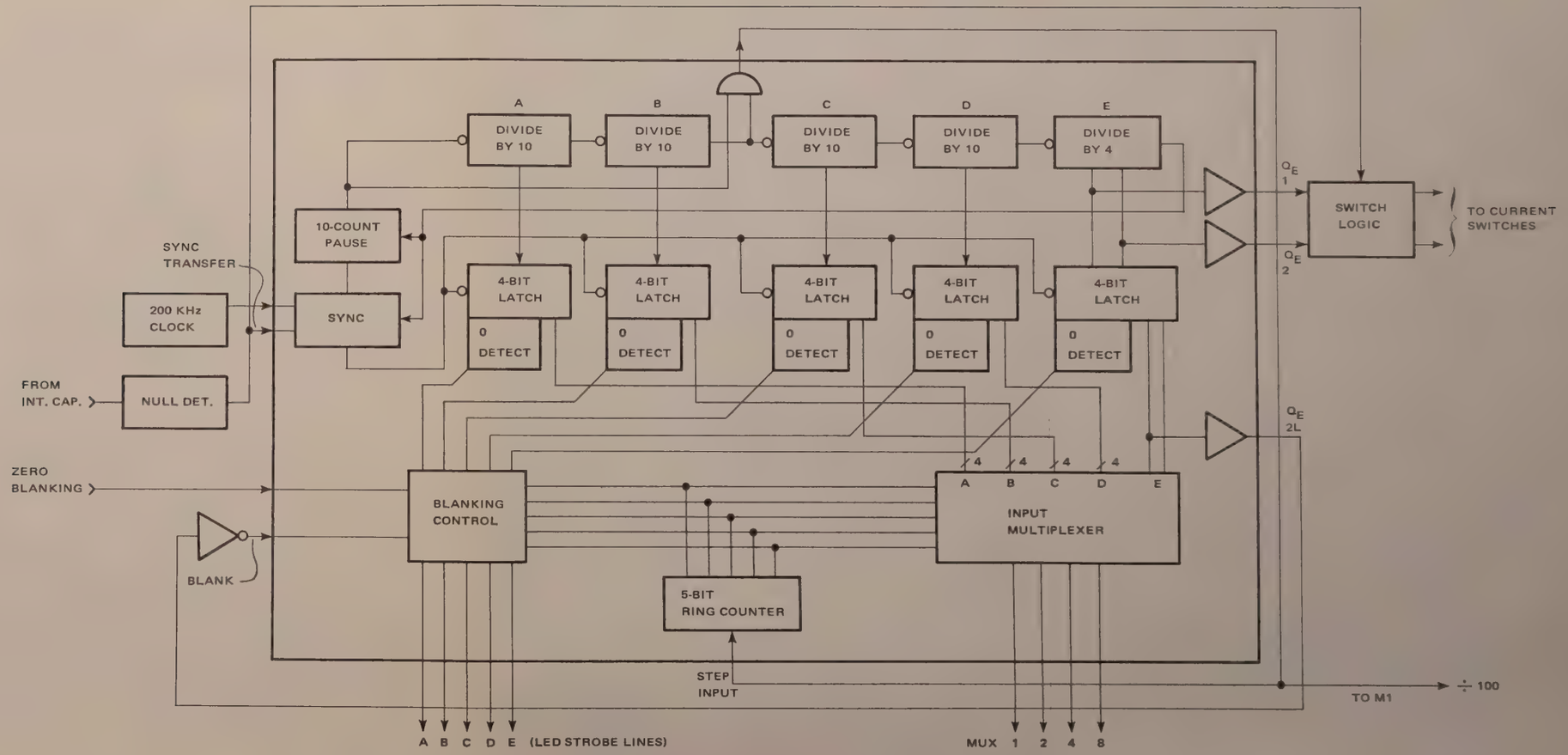
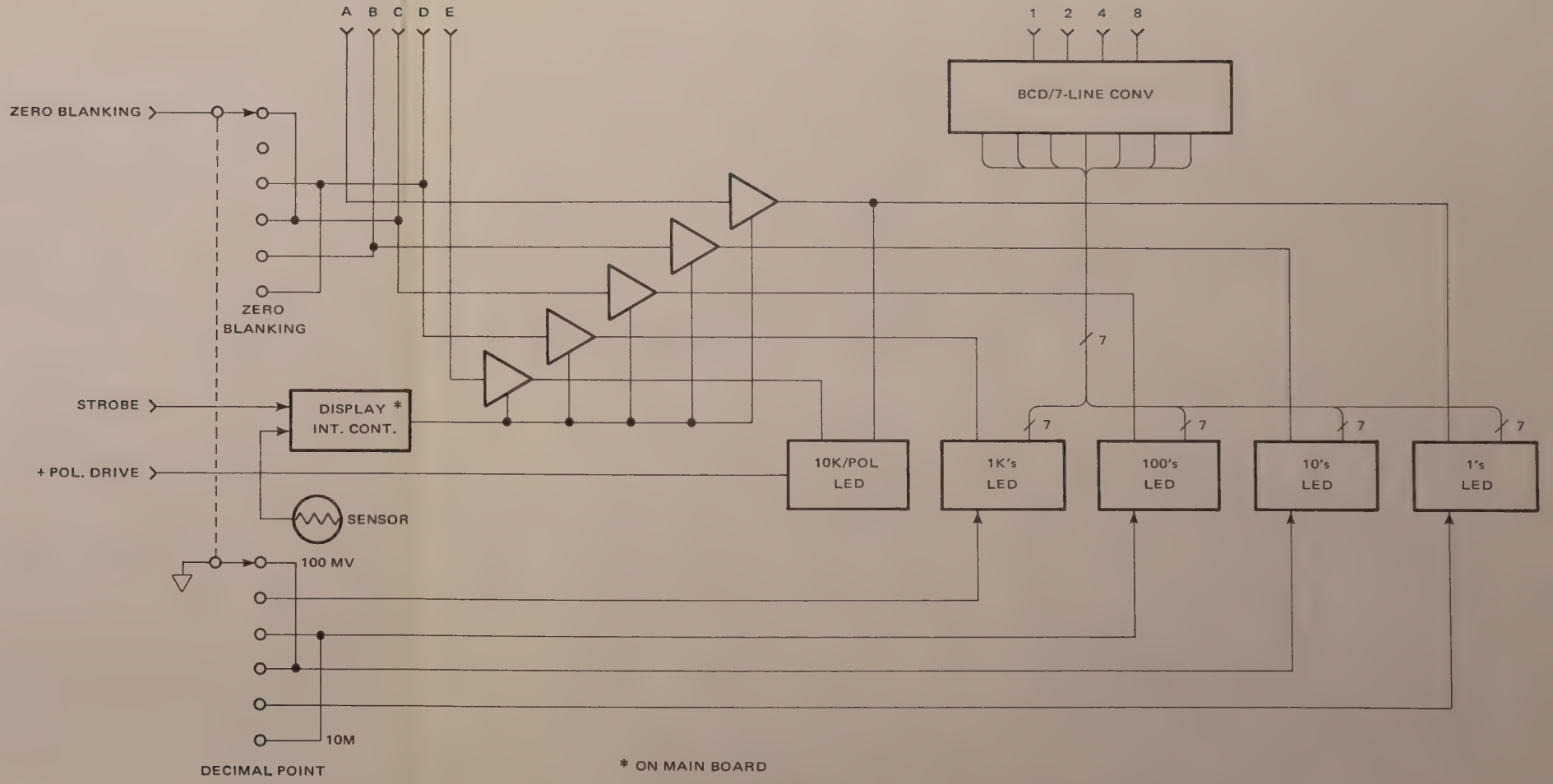


Figure 4.8 - Counter/Multiplexer



4-10 Figure 4.9 - Readout Circuitry

4.32 The counter advances from 00000 until a false signal is generated by the null detector, signifying the end of the reference integration period. The null detector signal commands the latches to store the data received from the counters.

4.33 The multiplexer presents the BCD data sequentially from each of the five latches at the 1, 2, 4, 8 outputs, beginning with latch "A". The multiplexer is driven by a five-bit ring counter which is stepped at a 2 kHz rate by the ÷100 output of the counter. The five output lines of the ring counter (A, B, C, D, E) are brought out of the chip (M3) via the blanking control circuit.

4.34 Readout.

4.35 The readout circuits portion, shown in figure 4.9, consist of four numeric LED's, a 1 and polarity LED, a BCD-to-7 line converter and the display intensity control circuitry. The BCD data from the multiplexer is applied to the BCD/7-Line converter. The output of the converter is applied in parallel to the four numeric readout units. The readouts are enabled sequentially beginning with the 1's LED by the five-bit ring counter outputs (LED strobes).

4.36 DISPLAY INTENSITY CONTROL.

4.37 The display intensity control monitors the ambient light, by means of a light sensor (R1) on display board, and adjusts the output of the display units to optimize readability. The circuitry, shown in figure 4.10, is a one-shot, with the pulse width controlled by the impedance of the light sensor and the triggering supplied by the ÷100 counter output (2 kHz). The output of the circuit is fed to five gates controlling the ring counter output lines to the display units. The positive portion of the pulse inhibits a percentage of the LED strobe pulses. The higher the ambient light, the shorter the one-shot pulse duration and the brighter the display.

4.38 BLANKING CONTROL.

4.39 The blanking circuitry is contained in integrated circuit M3 and requires only that data be provided to indicate where blanking is to occur. The circuit causes all the displays to blank when the instrument is in an overload condition or causes the insignificant zeros to blank to the left of the decimal point for normal readings. The circuit operates by inhibiting the LED strobe lines. Decimal position data is provided by a wafer of the range switch

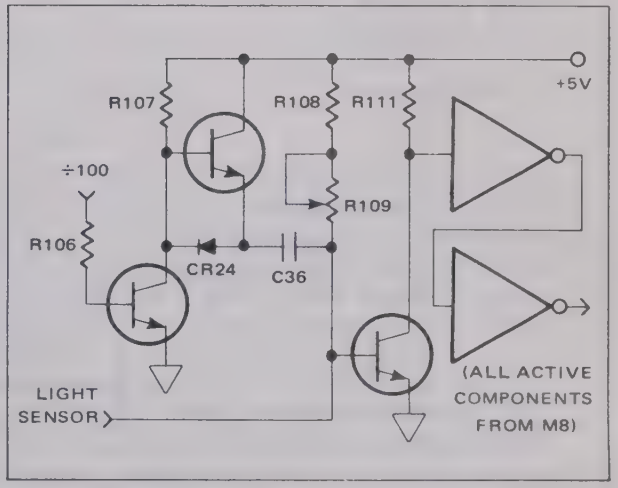


Figure 4.10 - Display Intensity Control

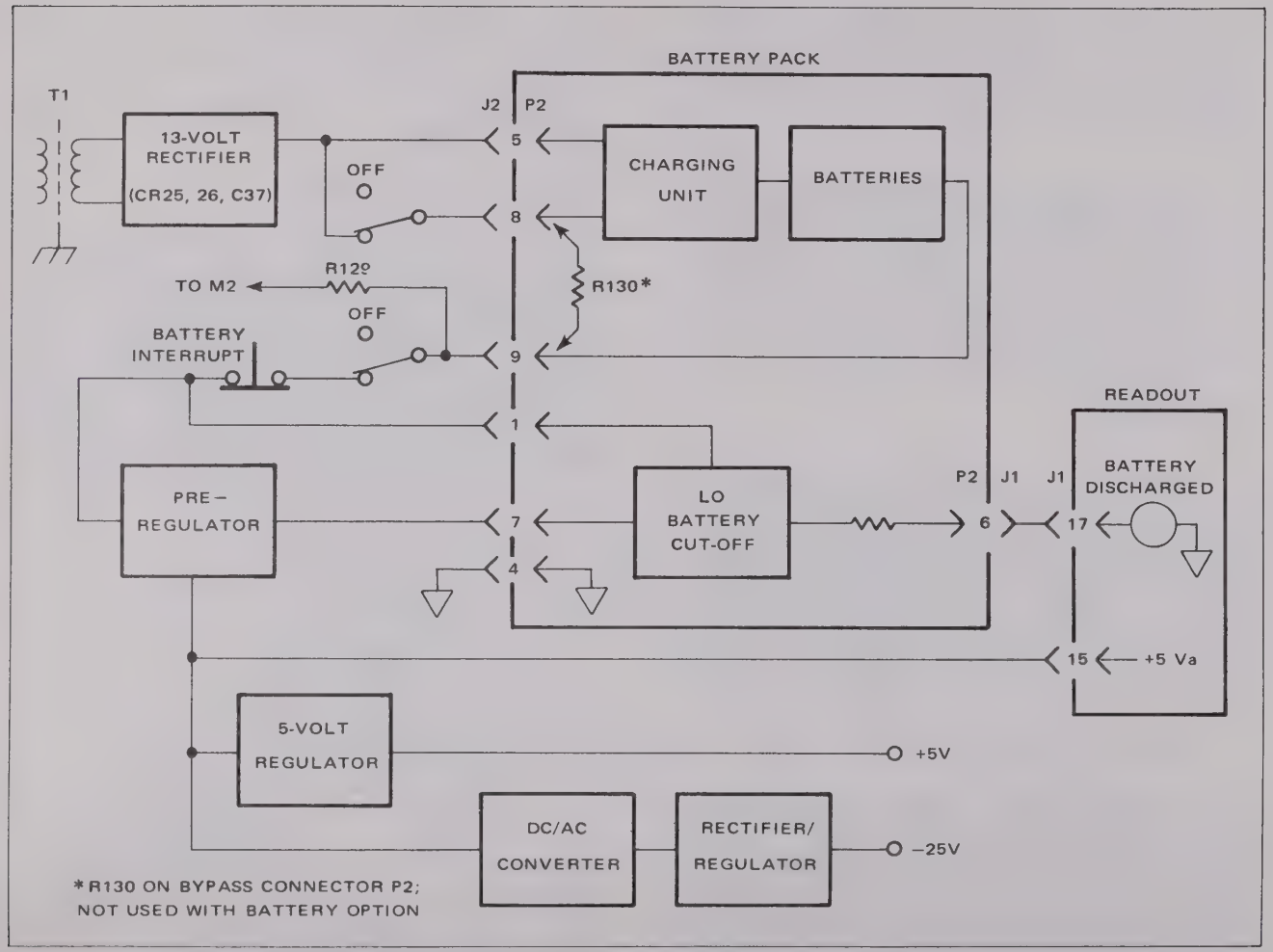


Figure 4.11 - Power Supply, Block Diagram

selecting the appropriate LED strobe line. The overload data is furnished by the inverted QE_2L output of M3 (indicating a counter state of 20,000).

4.40 Power Supply.

4.41 The power supply, shown in block diagram of figure 4.11, consists of a +13 volt, full-wave, unregulated supply; a +6 volt preregulator and low battery cutoff circuit; a +5 volt regulator; a DC to AC converter driving a −25 volt rectifier/regulator circuit; and, when included, the battery pack.

4.42 13-VOLT SUPPLY.

4.43 The +13 volt power supply, along with the transformer and power input circuitry, is shown in figure 4.12. The +13 volts is derived from diodes CR25 and CR26 and filtered by C37. The 13 volts is applied through resistor R130 to the preregulator of (if equipped with the battery option) to the battery pack. BATTERY INTERRUPT switch S203 opens this line to the preregulator when the front cover is closed to prevent accidental discharge of the batteries.

4.44 PREREGULATOR (5 VA).

4.45 The line from the battery to the preregulator is opened when the instrument cover is closed by interlock switch S203, BATTERY INTERRUPT. This prevents accidental discharge of the batteries if the cover is closed and the instrument is not turned off.

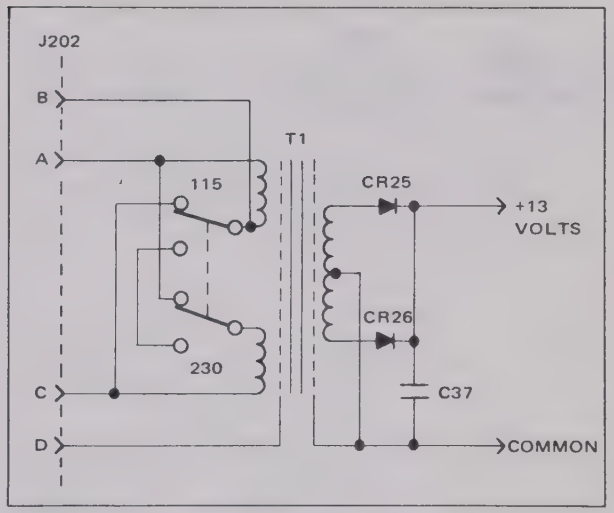


Figure 4.12 - +13 Volt Supply

4.46 The preregulator circuit (figure 4.13) provides power to the readout board and the +5 volt and −25 volt supplies. With the instrument operating from line power (without battery pack), the circuit is connected to the +13 volt supply through the battery pack bypass (P2) and reduces the +13 volt level to a regulated level of approximately +6 volts. With the battery pack installed, the output of the preregulator generally approximates the voltage level of the battery pack. If the battery level drops below 5.5 volts, the preregulator disconnects the batteries from the remainder of the circuitry to prevent further battery drain.

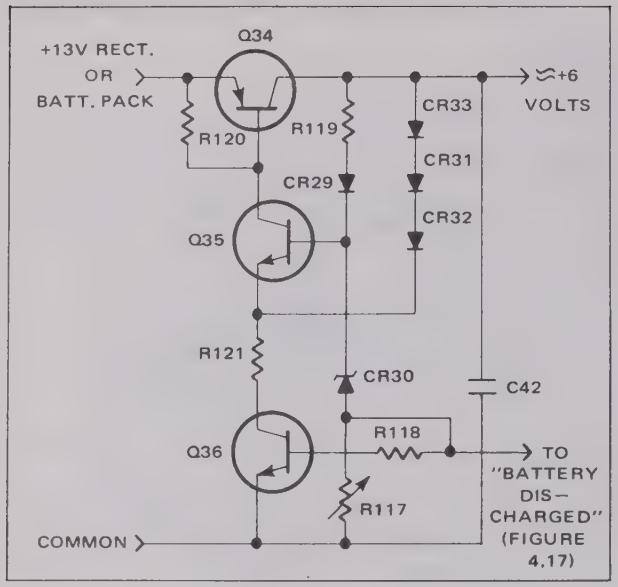


Figure 4.13 - Preregulator/Low Batt Cutoff

4.47 The circuit consists of a series regulator transistor (Q34) that is controlled by transistor Q35 referenced to zener CR30. Negative feedback for regulation is through diodes CR31, CR32, and CR33. When the input to the circuit drops below +5.5 volts, transistor Q36 cuts off and the preregulator output goes to zero.

4.48 FIVE-VOLT SUPPLY.

4.49 The five-volt regulator is shown in figure 4.14. Transistor Q39 is used as a series regulator with Q40 controlling the bias to Q39. Zener diode CR39, operating only at the initial start-up period, supplies current to the base of Q40, biasing Q39 on and supply current for the reference zener CR36. Negative feedback for regulation is through diodes CR37 and CR38. The base level of Q40 is set by potentiometer R124 to provide +5 volts output.

4.50 –25-VOLT SUPPLY.

4.51 The –25-volt supply (figure 4.15) consists of a transformer coupled push-pull oscillator operating at a frequency of approximately 10 kHz and a rectifier/regulator circuit. Starting bias for the power oscillator circuit is through R123. Diodes CR34 and CR35 limit the reverse bias across the base emitter junctions to 0.7 volts.

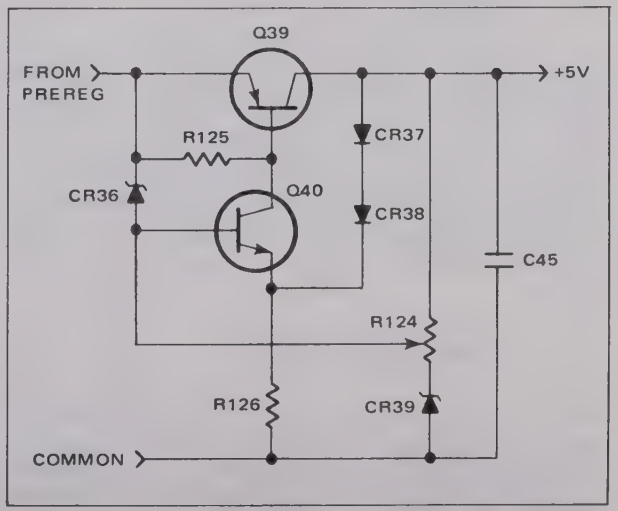


Figure 4.14 - +5 Volt Supply

4.52 The Rectifier/Regulator converts the square wave output from the secondary winding of the DC to AC converter to negative dc through rectifier bridge CR40, CR41, CR42, and CR43 and filter capacitor C46. The – DC powers the –25V regulator consisting of transistor Q41. The regulator is a series emitter follower type with the reference supplied by zener CR44.

4.53 BATTERY PACK.

4.54 The battery pack consists of 5 rechargeable batteries, a fixed current charging unit, a thermal cutoff circuit, and a BATTERY DISCHARGED circuit (figure 4.16).

4.55 The batteries are nickel-cadmium 1.25 volt cells connected in series to provide about 6.25 volts. The cells

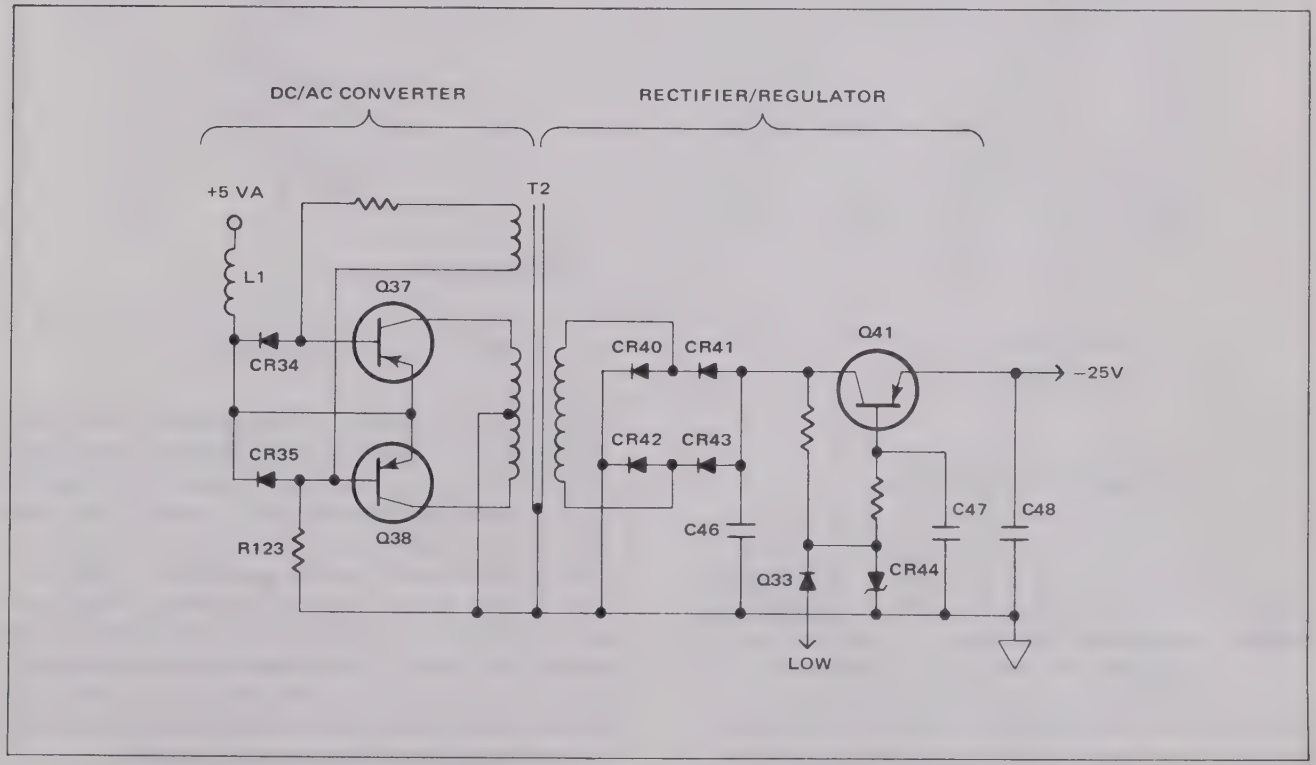


Figure 4.15 - –25V Supply

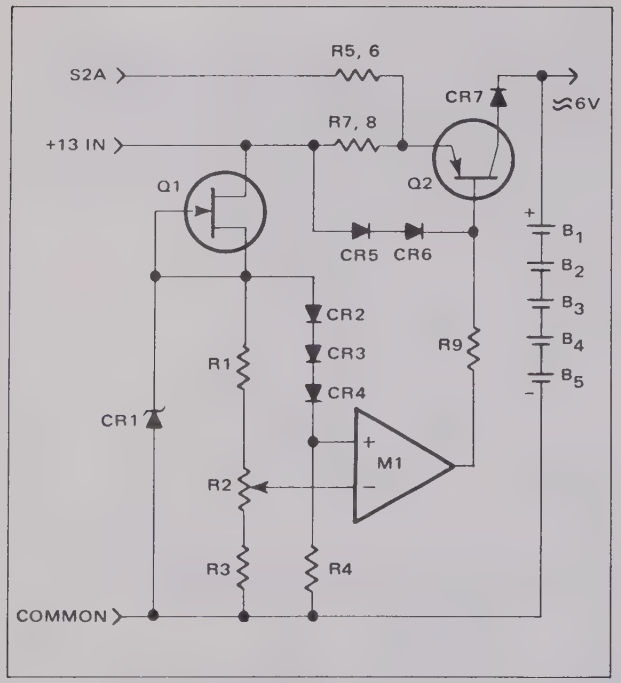


Figure 4.16 - Battery Pack

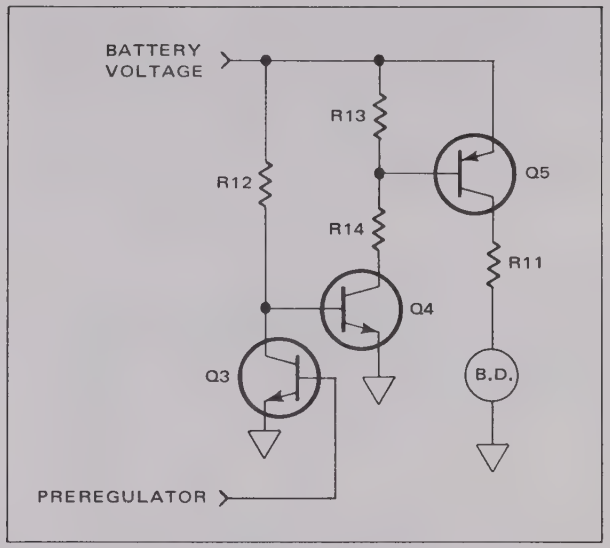


Figure 4.17 - "Battery Discharged" Circuit

are charged by a constant current generator consisting of transistor Q2 and diodes CR5 and CR6. The generator supplies approximately 400 milliamps to the cells from the +13 volt supply with the DMM function switch set to OFF and about 800 milliamps with the function switch set to any other position. The amount of current is determined by Q2 emitter resistors R5, R6, R7, and R8. Diodes CR2, CR3, and CR4, positioned in close proximity to the power cells, provide the temperature sensing for the thermal cut-off circuit. The circuit consists of a bridge network supplied by a constant voltage source. The output of the bridge drives an operational amplifier (M1). The voltage source is made up of a constant current generator Q1 driving zener CR1 to provide +5.6 volts to the bridge. If the heat generated by the batteries due to charging reaches 60°, the voltage drop across the three diodes decreases sufficiently due to the temperature to cause the output of M1 to go positive. This removes the bias from transistor Q2 and current is prevented from flowing into the batteries.

4.56 A circuit consisting of transistors Q3, Q4, and Q5 monitors the battery voltage and the battery cutoff line from the preregulator. The preregulator drops this line to zero when the battery voltage drops below 5.5 volts (see paragraphs 4.46 and 4.47). When this occurs, transistor Q3 cuts off, Q4 turns on, Q5 turns on and applies a positive voltage, through R11, to the BATTERY DISCHARGED indicator.

4.57 SIGNAL FLOW.

4.58 Signal flow for each of the operating modes is described in Section 5, paragraph

5.1 DISASSEMBLY (FOR CALIBRATION).

WARNING

Removal of covers exposes potentially lethal voltages. Avoid contact with internal electrical connections while unit is connected to AC Power source.

a. Open front cover by unfastening the latches on the side of the front cover. Remove cover by lifting it from the hinges.

b. Remove six retaining screws on front panel (figure 5.1).

c. Pull chassis forward and out of case (figure 5.2).

NOTE

A desiccant packet, located inside the sealed outer case (figure 5.2), must be replaced each time the case is opened for more than five minutes. The desiccant consists of a moisture adsorption packet and a humidity indicator. New packets are supplied in a heat-sealed outer bag. The outer bag must not be punctured or opened until ready for use. When the inner bag is opened, the circle on the humidity indicator must be blue. If not, the packet is defective. Once the sealed bag is opened, the packet must be installed and the instrument sealed within five minutes.

Additional adsorption packets may be obtained from:

Coast Engineering Laboratory
13508 S. Normandie
Gardena, California Part No. DEEC-1

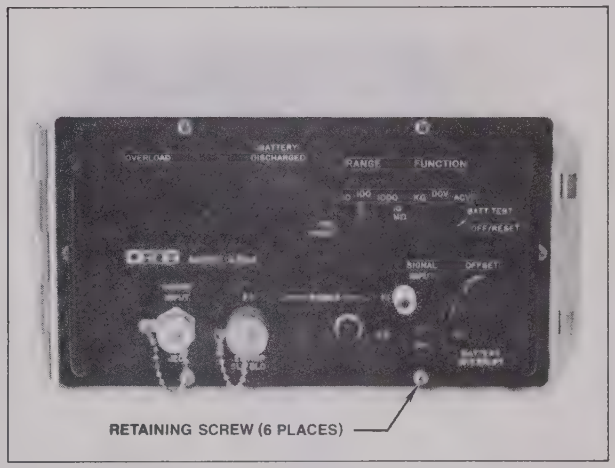


Figure 5.1 - Location of Retaining Screws

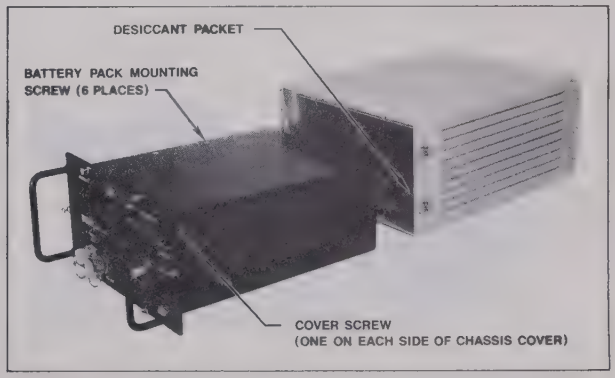


Figure 5.2 - Chassis Removed from Case

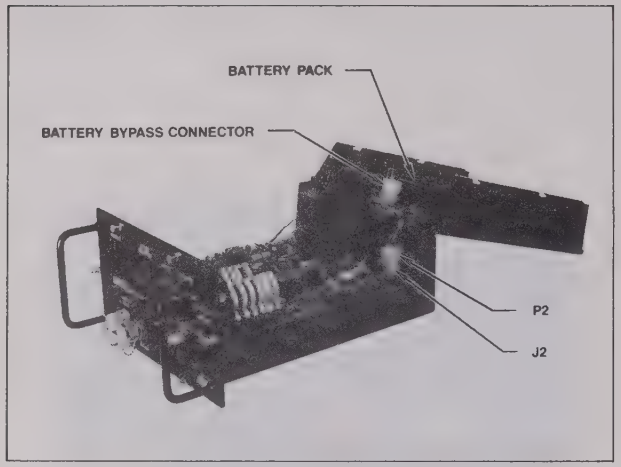


Figure 5.3 - Chassis Cover Opened

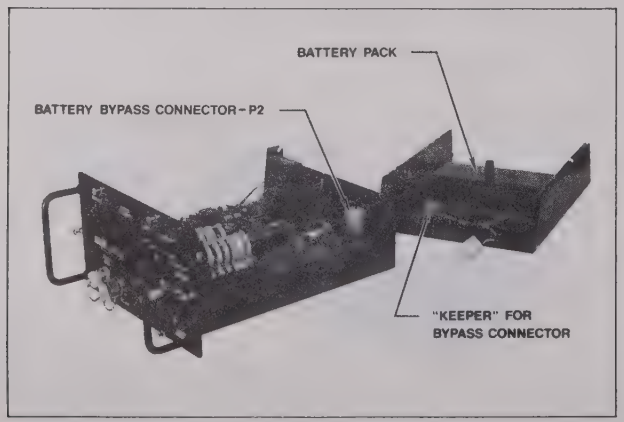


Figure 5.4 - Top Cover Removed

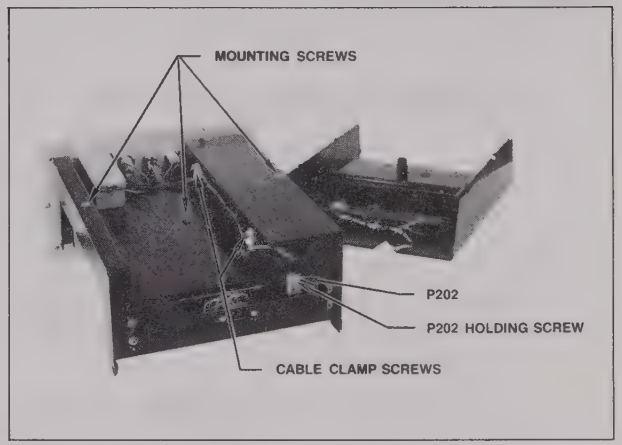


Figure 5.5 - Bottom of Chassis

d. Remove two cover screws and open hinged top cover (figure 5.3). All calibration points are now accessible. If desired, the top cover can be removed entirely by unplugging battery pack connector P2 and lifting top. *For operation with the battery pack removed, it is necessary to connect battery bypass connector P2 (stored on battery pack) to J2 (figure 5.4).*

5.2 DISASSEMBLY (FOR PARTS REPLACEMENT).

5.3 For access to the bottom (solder side) of the printed circuit board, the following additional steps are required (after completing 5.1d).

a. Place instrument upside down on bench (figure 5.5). Remove screw holding connector P202. Disconnect P202.

b. Remove three bottom cover mounting screws and the two cable clamp screws.

c. Remove bottom cover by sliding it toward rear of instrument. The bottom side of the p-c board is now accessible (figure 5.6).

5.4 BATTERY PACK REMOVAL.

5.5 The following procedure is required for battery replacement or for replacing other parts in the battery pack.

a. Remove top cover of chassis by performing steps 5.1 (a through d).

b. Remove the six battery pack mounting screws from top side of cover (shown in figure 5.2). The four outer mounting screws have nuts which must be held from the inside. Support the battery pack with free hand while removing the last screw to prevent dropping battery pack.

c. Remove the power transistor mounting screw and the battery pack cable clamp screw (the remaining two screws through top cover). The entire battery pack is now free of the instrument (figure 5.7).

d. Remove the six battery pack cover screws (figure 5.7).

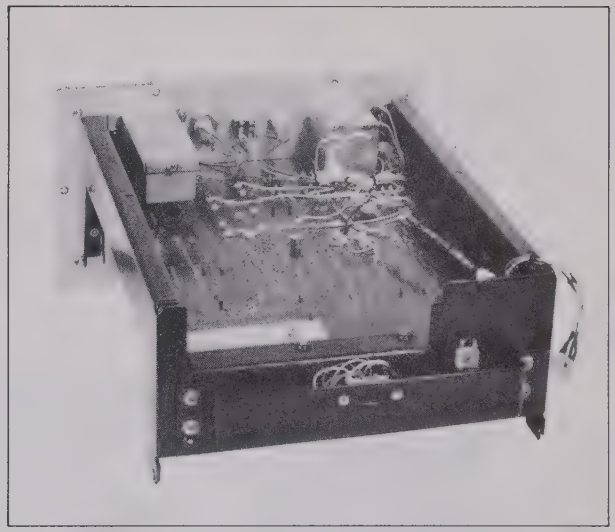


Figure 5.6 - Bottom Cover Removed

Figure 5.7 - Battery Pack Removed

NOTE

To avoid dropping of the batteries and possible damage to the pigtails soldered to them, it is recommended that masking tape be used to fasten the plastic cover to the battery pack p-c board before the cover screws are removed. The battery pack is then placed on an insulated surface with the cover up. The tape is then cut or pulled off and the cover removed.

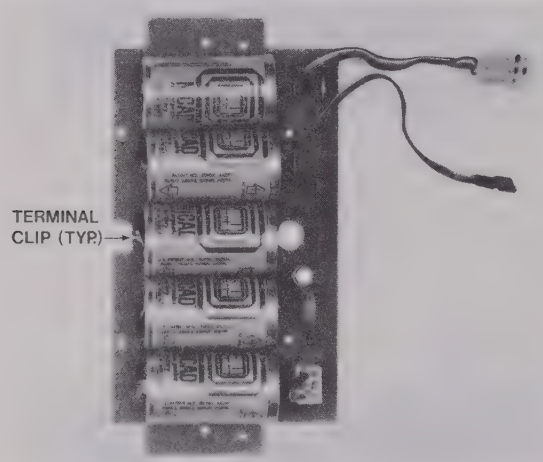


Figure 5.8

e. Remove plastic cover. To replace batteries, unsolder pigtails from clips on battery terminals (figure 5.8). Remove batteries. Table 5.1 is a chart listing recommended replacement batteries.

Table 5.1 - Replacement Batteries

Manu	P/N
Gould	4.0SC (Lo Temp)
Marathon	S103 (Lo Temp)
G. E.	XGCW4.0ST (Lo Temp)

f. Install new batteries (positive side toward components at edge of board).

g. Solder pigtails onto terminal clips of new batteries.

h. Replace cover. Reinstall battery pack as described under "Battery Pack Installation", paragraph 5.6.

5.6 BATTERY PACK INSTALLATION.

a. For original installation, remove top cover of chassis by performing steps 5.1 (a through d).

b. Hold battery pack in position on the top cover (as seen in figure 5.4). Install two 8-32 x 3/8 self-tapping screws through the center two of the six battery pack mounting screw holes on top cover (figure 5.2). Install the four outer 8-32 mounting screws with a flat washer, internal lock washer, and hex nut on the inside of the cover. Tighten all six screws.

NOTE

All hardware supplied with battery pack.

c. Install battery cable clamp with a 6-32 screw (from top side of cover) and hex nut at location shown in figure 5.4.

d. Install power transistor with a mica washer between the cover and the gold surface of the transistor secured by a 4-40 screw (from top side of cover), #4 flat washer, and hex nut.

e. Place top cover hinge pins into position on chassis hinge slots as shown in figure 5.3.

f. Remove bypass connector from J2 on main p-c board and place on "keeper" connector on battery pack (figure 5.4). Connect battery pack cable connector P2 to J2. This completes the installation of the battery pack. Check the battery pack voltage adjustment, paragraph 5.14.

5.7 CALIBRATION.

5.8 This procedure is recommended to maintain the Model 4324 operating within its published specifications. An abbreviated form of this procedure is silkscreened under the DMM top cover.

5.9 Required Equipment.

5.10 The equipment required or acceptable substitutes are listed in Table 5.2.

5.11 Preparation.

5.12 Perform steps of disassembly procedure, paragraph 5.1. Apply Power to the DMM and allow 30 minutes for warmup time. Refer to figure 5.9 for location of adjustments.

5.13 Power Supply Adjustment.

a. With instrument operating on line voltage, verify a voltage of $-25V \pm 2V$ on the -25 volt bus (this can be measured at right side of R97). Verify a voltage of +5.5V to +6.7V at L1.

b. Connect voltmeter between anode of CR37 and ground. Adjust R124 for a voltmeter reading of +5.0 volts $\pm$ 10 mV. Remove power from instrument.

c. Disconnect battery pack and install bypass connector P2. Connect power input to Variac. Connect scope between P2-5 and ground. Sawtooth waveform will appear on scope. Adjust Variac until negative portion of waveform is at +5.5 volts. Adjust R117 (battery drop-out adjustment) to the point where the display blanks out.

5.14 Battery Charging Rate Adjustment.

a. Set FUNCTION switch to BATT TEST, RANGE to 100.

b. Measure voltage at pin 3 of integrated circuit M1 on battery pack (figure 6.3).

Table 5.2 - Calibration Equipment Required

Name	Use	Required Spec	Recommended Type
microvoltmeter	set "+" 480 mV current zero	10 μV Resolution .1% accuracy	Fluke 845AR
variable transformer	battery drop-out adj.	115V units: 95 - 135 VAC 230V units: 210 - 250 VAC	Eico 1078
oscilloscope	AC Converter zero battery drop-out adj.	at least 1 mV/Div sensitivity	Tektronix 503
DC Source	DC range calibration	6 place accuracy $\pm$ 1000V DC	Fluke 332A
ohms standard	K ohms calibration	.05%	ESI DB 62
AC Source	AC calibration	.05%	HP 745 & 746
insulated adjustment tool			JFD 5284
clipleads	approximately 12" long made with Mueller mini-gator clips & slip-on isolators.		

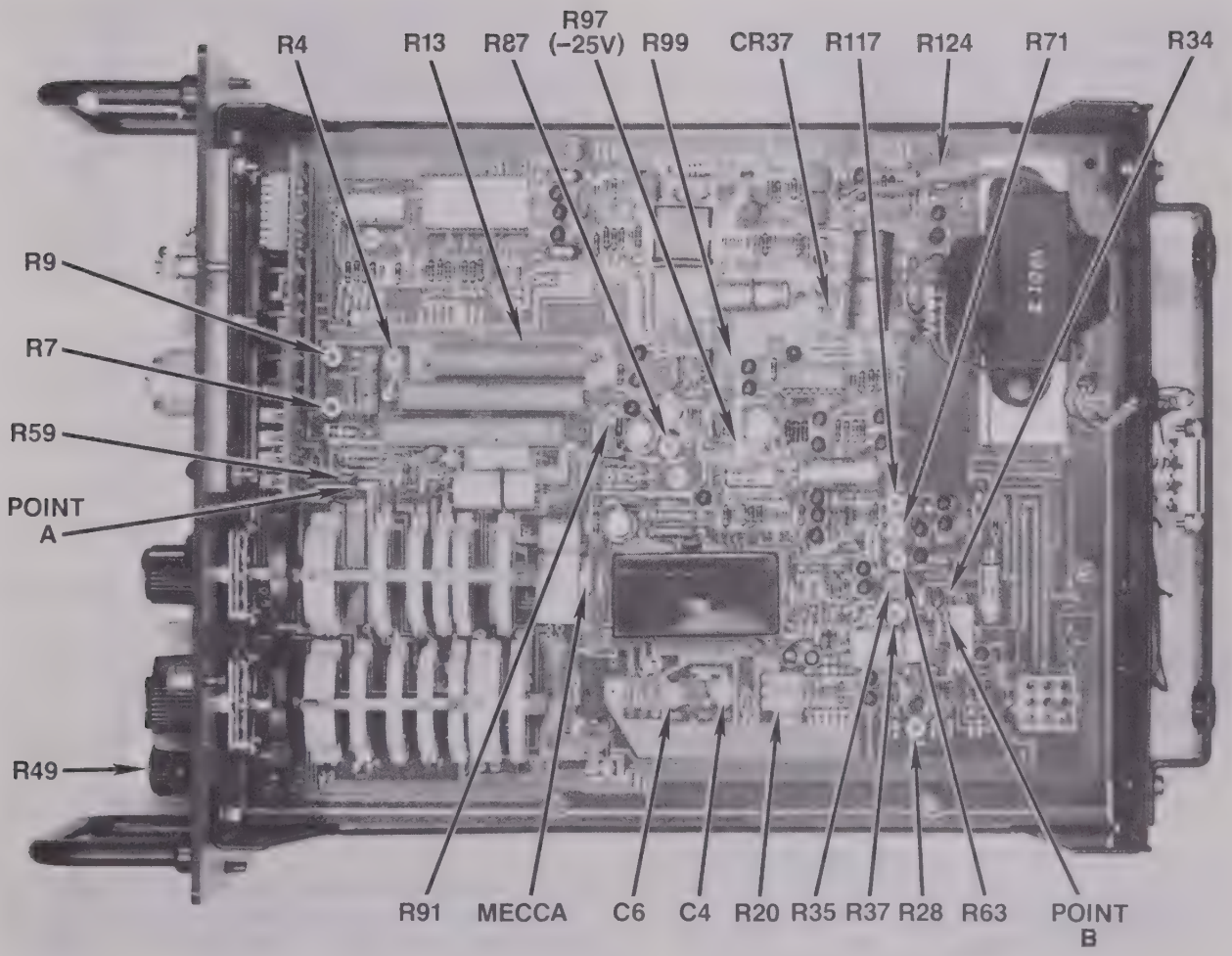


Figure 5.9 - Adjustment Locations

c. Connect voltmeter to pin 2 of M1. Adjust R2 for voltage obtained in step b plus 245 mV.

5.15 DC Calibration.

a. Connect a jumper between the high and low input terminals. Select the DC function and the 100 mV range.

b. Connect the low input of the microvoltmeter to "Mecca" (the instruments' analog reference zero point) and the high input to point A of resistor R59. Adjust potentiometer R63 for a microvoltmeter reading of zero ± 10 μV. Remove the microvoltmeter leads.

c. Adjust the front panel OFFSET potentiometer R49 for zero with alternating plus and minus polarity indicators on the DMM readout.

d. Connect the DC source to the DMM input and set the standard at +.1 mV. Adjust R71 for a DMM readout of +.10. Remove dc source and connect jumper across input.

e. Repeat steps c and d until no adjustments are required.

f. Select the range and set the DC source to the voltages indicated in Table 5.3 and adjust the indicated potentiometers for readouts equal to the input voltage ±2 digits.

Table 5.3 - DC Range Adjustments

Range	Input Voltage	Range Adjustment
1	+1.9000 VDC	R99
10	+19.000 VDC	R4
100	+190.00 VDC	R7
1000	+1000.0 VDC	R9

g. Reduce the DC source voltage and remove input to the DMM.

5.16 Resistance Calibration.

a. Select Kilohms function and the 1K range.

b. Connect a 1K ohm resistance standard to the DMM input terminals.

c. Adjust R91 for a DMM readout of 1.0000.

d. Select 10 MΩ range; connect a 10 MΩ resistance standard to the input terminals.

e. Adjust R87 for a DMM readout of 10.000.

f. Repeat steps a, b, c, d, and e until all conditions are satisfied. Remove DMM input leads from the Kilohms standard.

Table 5.4 - AC Range Adjustments

Range	Input Voltage	Input Frequency	Range Adjustment
1	1.9000	15 kHz	C6
10	19.000	15 kHz	C4

5.17 AC Calibration.

a. Select AC function and the 1V range.

b. Jumper the input terminals of the DMM and connect the oscilloscope low input to "Mecca" and the high input to wiper (center-terminal) of R28. Adjust R28 for a scope display of −1V.

c. Remove the oscilloscope leads and the jumper from the DMM input terminals. Connect input to ac source of 1.9V at 400 Hz. Adjust R20 for a readout of 1.9000.

d. Apply AC voltage inputs as shown in Table 5.4 and adjust the appropriate control for a DMM readout equal to the input voltage.

5.18 TROUBLESHOOTING.

5.19 The following procedure consists of a table listing possible instrument problems and a set of signal flow diagrams. The table indicates the circuit that could cause the malfunction, describes the normal output for the circuit, and indicates the paragraphs of the theory section that describe the circuit operation. The flow charts provide voltage levels, current levels and waveforms of the attenuator and G_m converter section for each function. The data provided on the charts, with the exception of the battery function, is for full scale input on the 10 range.

5.20 Procedure.

5.21 Check to be certain that the proper fuse and line voltage selector switch have been chosen and then perform the following steps:

a. Determine the exact nature and extent of the problem by performing the specification verification procedure (Section 3) and note which instrument operations fail to perform properly.

b. With power removed, perform the disassembly procedure described in paragraph 5.1.

c. Based on the information obtained in step 1, refer to the symptoms of Table 5.5. Select the symptoms that most nearly describe the problem observed and perform the appropriate troubleshooting operations.

5.22 Signal Flow.

5.23 Figures 5.10 through 5.13 and the following paragraphs cover the routing of the input signal through switches S1 (RANGE) and S2 (FUNCTION) and the major components for each Function mode. The heavy line of each drawing denotes the major signal path.

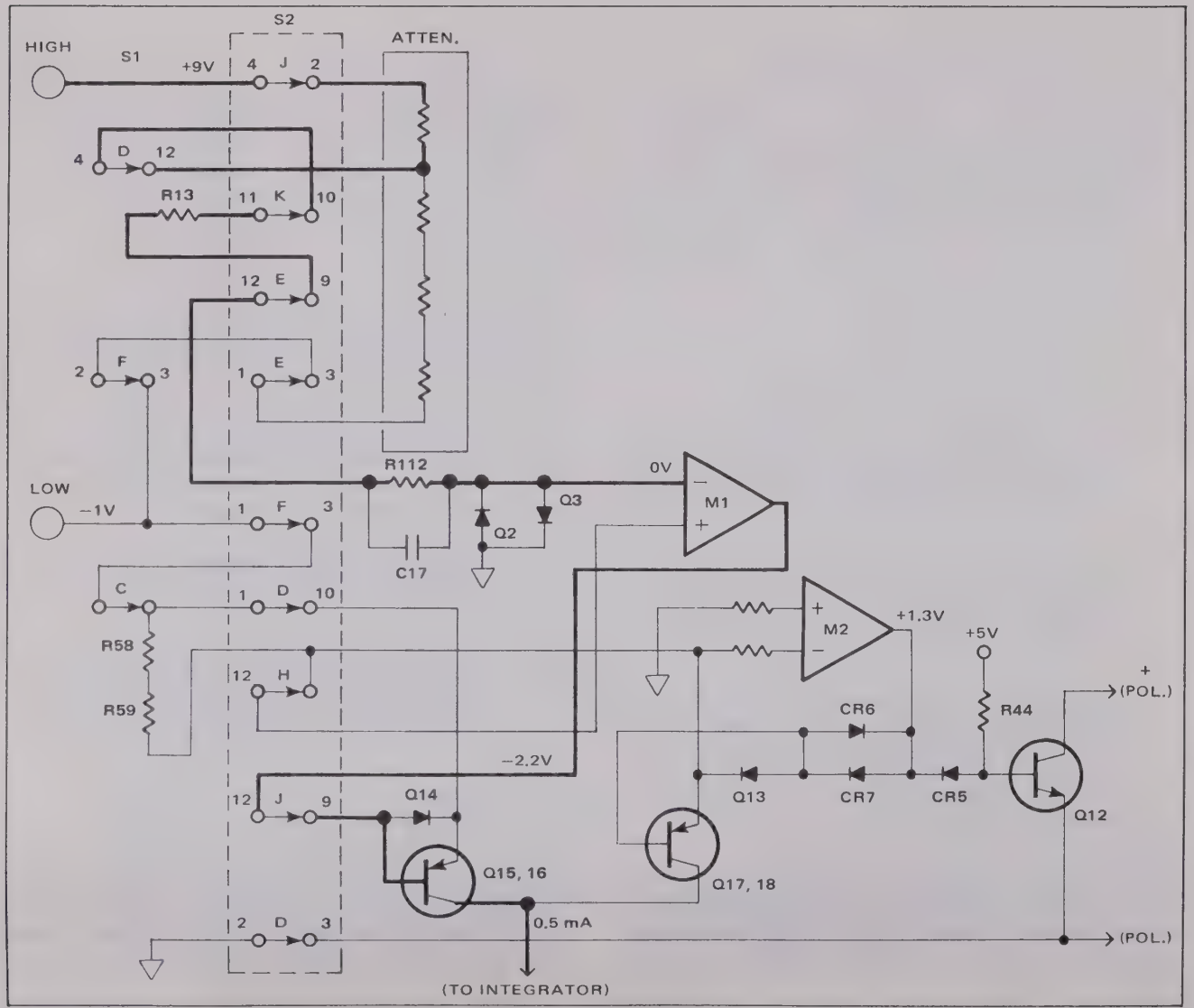


Figure 5.10 - DCV Mode, 10 Range

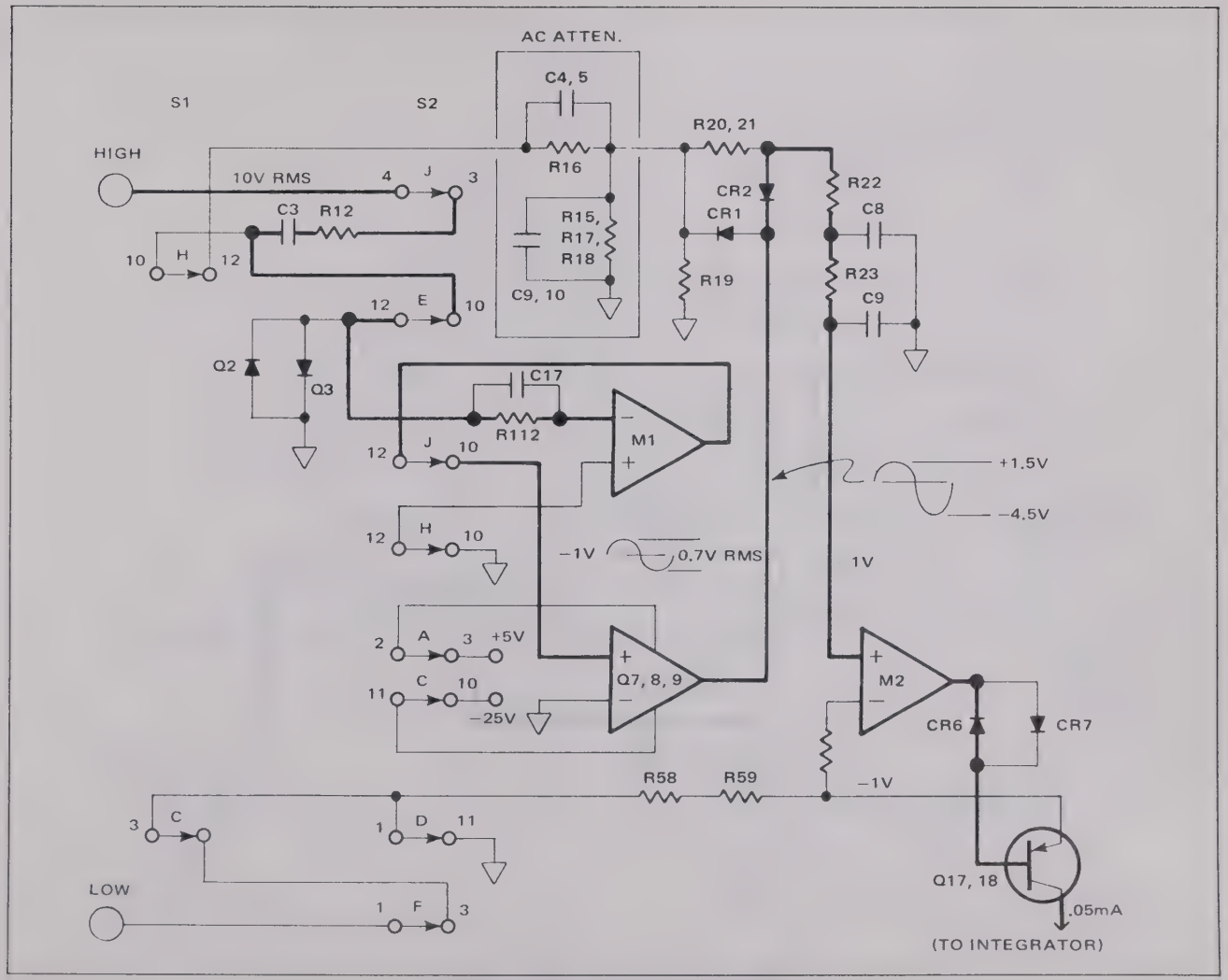


Figure 5.11 - ACV Mode, 10 Range

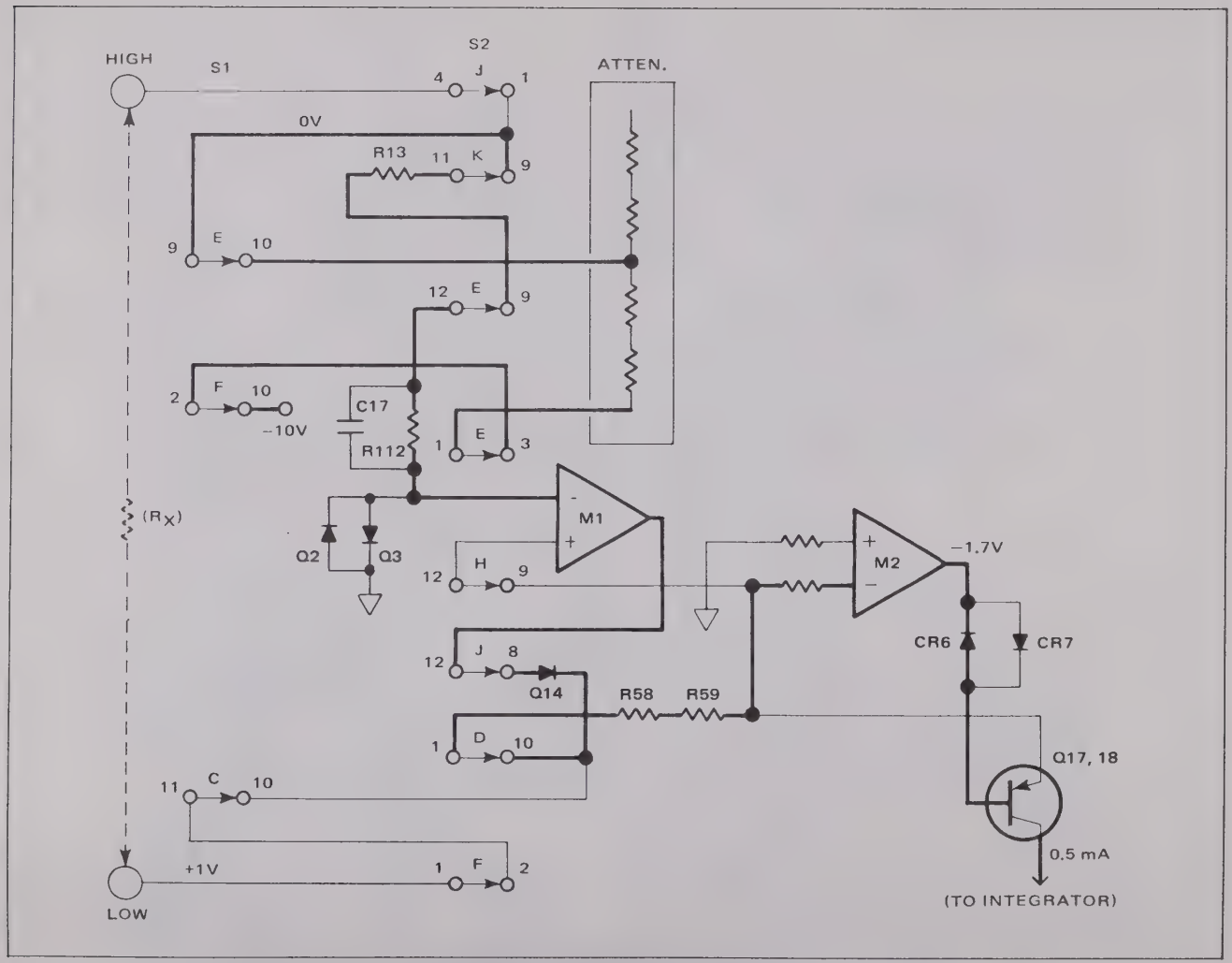


Figure 5.12 - KOHMS Mode, 10 Range

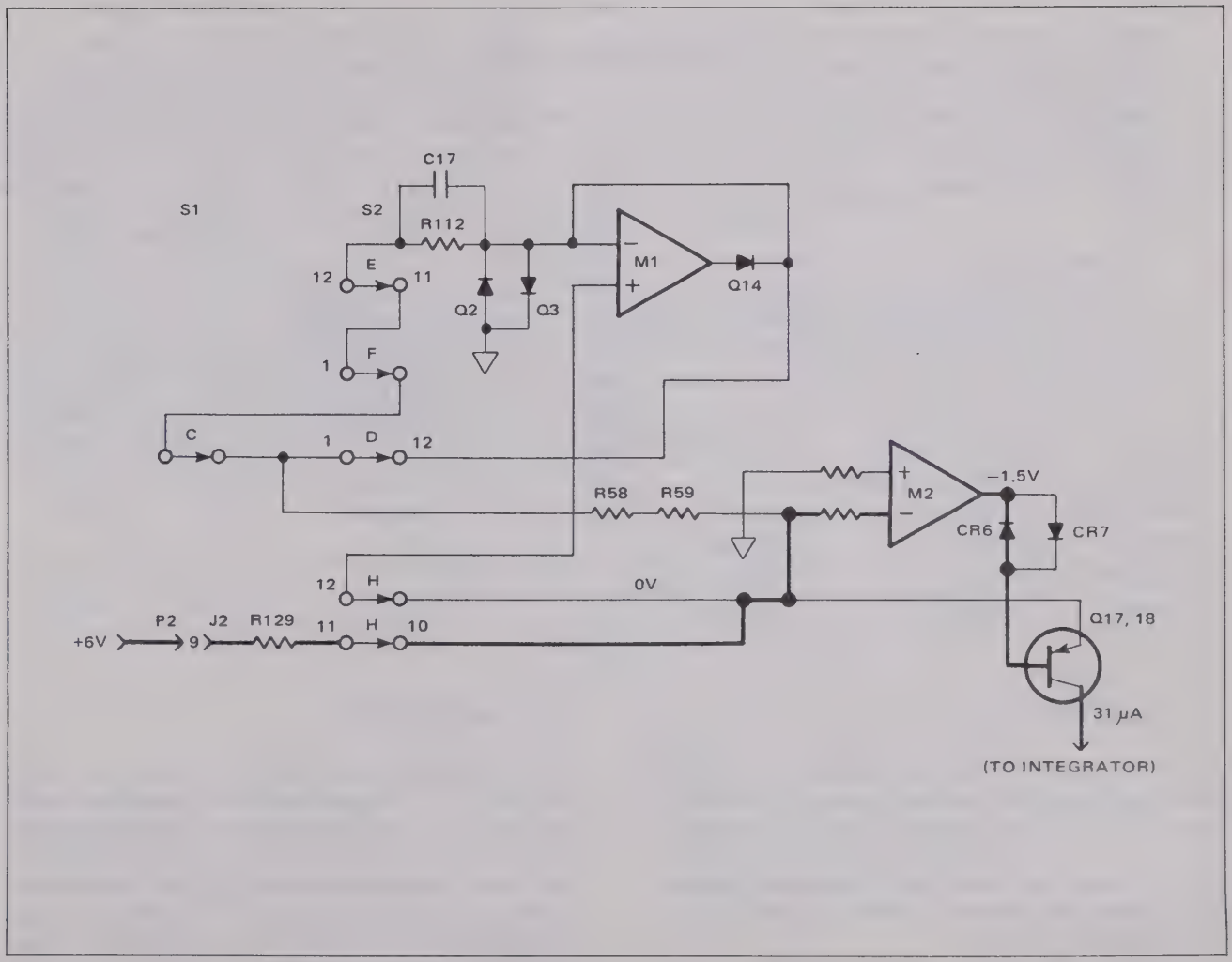


Figure 5.13 - Battery Mode

Table 5.5 - Troubleshooting

Symptom	Probable Cause	Circuit	Test Point	Signal	REFERENCE	
					Figure	Paragraph
DISPLAY BLANK	No Power	Power Supply	J2-8	+13V ± 50%	4.12	4.43
			Q34 Collector	+6.25 ± 12%	4.13	4.45
			CR37 Anode	+5V ± 5%	4.14	4.48
			C48 (–)	–25V ± 5%	4.15	4.50
	No Clock Pulse	Clock	M3-1	200 kHz Clock	4.7	4.29
	Counter Inoperative	M2	M3-16	200 ms Sq Wave	4.8	4.32
			M3-18	100 ms Sq Wave	4.8	4.32
			M3-11	2 kHz Signal	4.8	4.34
	Display Inhibited	Intensity Ckt	M8-11		4.10	4.38
OVERLOAD	Inverter Inoperative	Q34	M3-9	Logic True	4.8	4.40
DOES NOT ZERO	Insufficient Offset Current	Offset Generator	Q19	0.5 μA	4.3c	4.17
READING ERROR	I_S Error	G_m Converter			4.3	4.13
	I_R Error	I. Ref. Gen.		0.5 mA	4.4	4.19

5.24 DCV FUNCTION.

5.25 The signal flow with the instrument in the DCV measurement mode for a positive input signal is shown in figure 5.10. The attenuator reduces a full scale input (+10 volts) to +1 volt for conversion by the G_m converter. With the positive input, the output of operational amplifier M2 is positive and transistor conducts, causing the plus polarity indicator to light.

5.26 ACV FUNCTION.

5.27 The signal routing for AC measurements is shown in figure 5.11. The input signal is fed through resistor R12 and capacitor C3 to a summing node at the inverting input of operational amplifier M1. The output of M1 drives a high output impedance amplifier (Q7, Q8, Q9) that drives rectifying diodes CR1 and CR2. The half-wave current flowing through the diodes is recombined across resistor

R19. The resulting AC signal developed across R19 is fed through the AC attenuator to the summing node. The negative half wave voltage, developed across resistors R20, R21 is filtered through a pi network and fed to the non-inverting input of M2 for conversion to a proportional current (I_S).

5.28 KOHMS FUNCTION.

5.29 The signal routing for resistance measurement (10K range) is shown in figure 5.12. The negative 10 volts output from the OHMS reference is routed through the attenuator to draw 100 μA from the summing node at the inverting input of operational amplifier M1. The output of M1 goes positive, driving the LOW input terminal positive and supplying positive current through the resistance being measured (R_X) to the summing node. The circuit stabilizes when the current through the resistor (R_X) equals the reference current (100 μA). The voltage developed across R_X is converted by M2 to a proportional current (I_S).

5.30 BATTERY FUNCTION.

5.31 The signal flow for the battery measurement function is shown in figure 5.13. The operational amplifier M1 and the normal current determining resistor (R58 and R59) are switched to analog common. The Battery voltage is converted into a proportional current through R1 (located on the battery pack) and fed to operational amplifier M2 to generate I_S.

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6.10	Layout, Test Probe (Option 87)	6-12

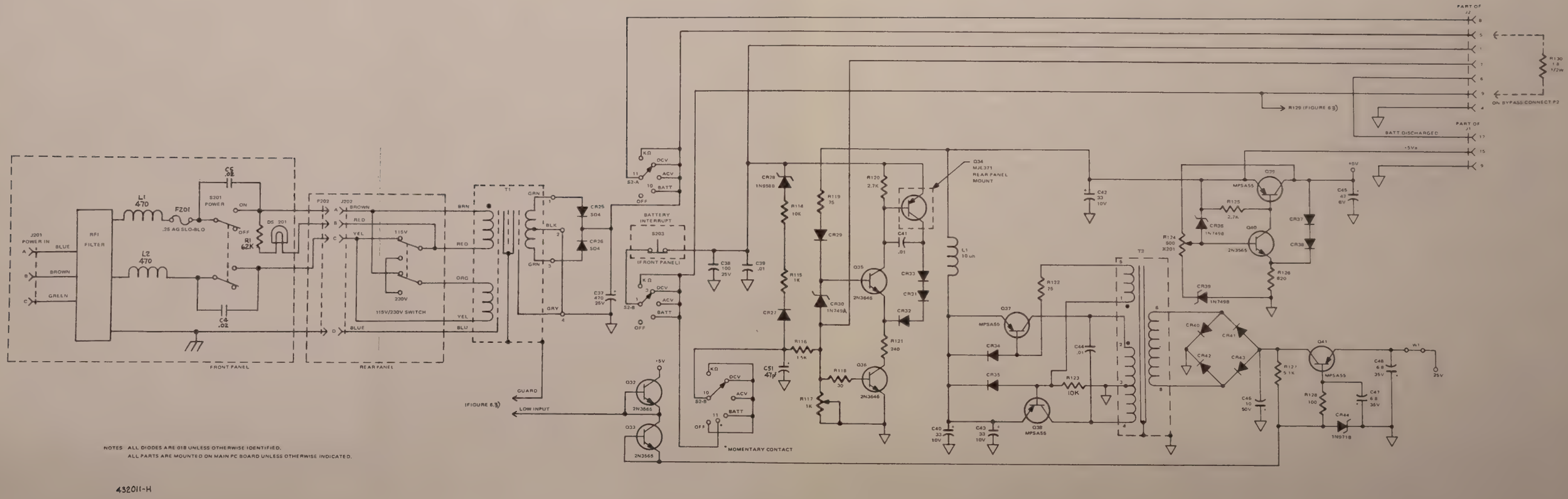
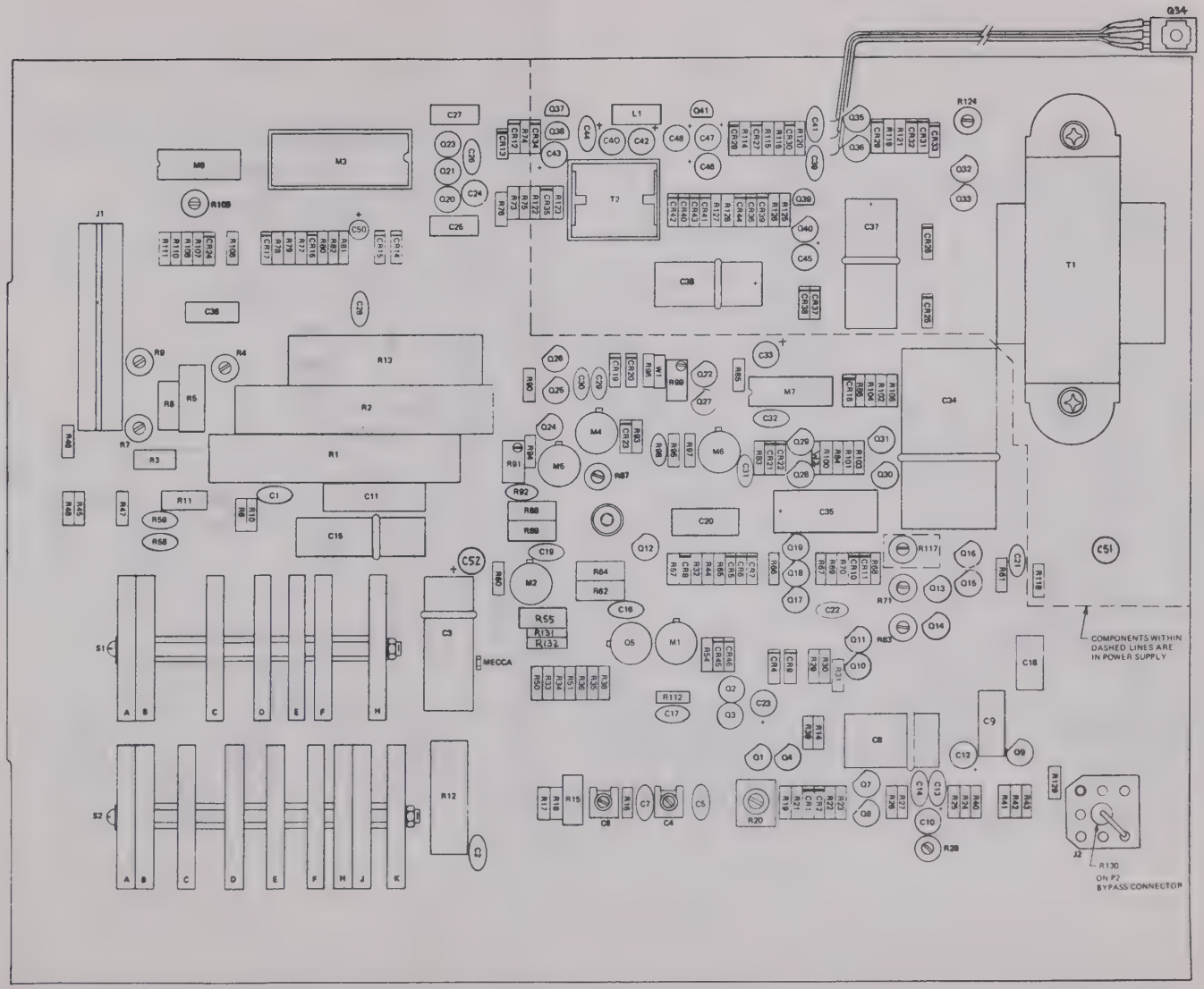
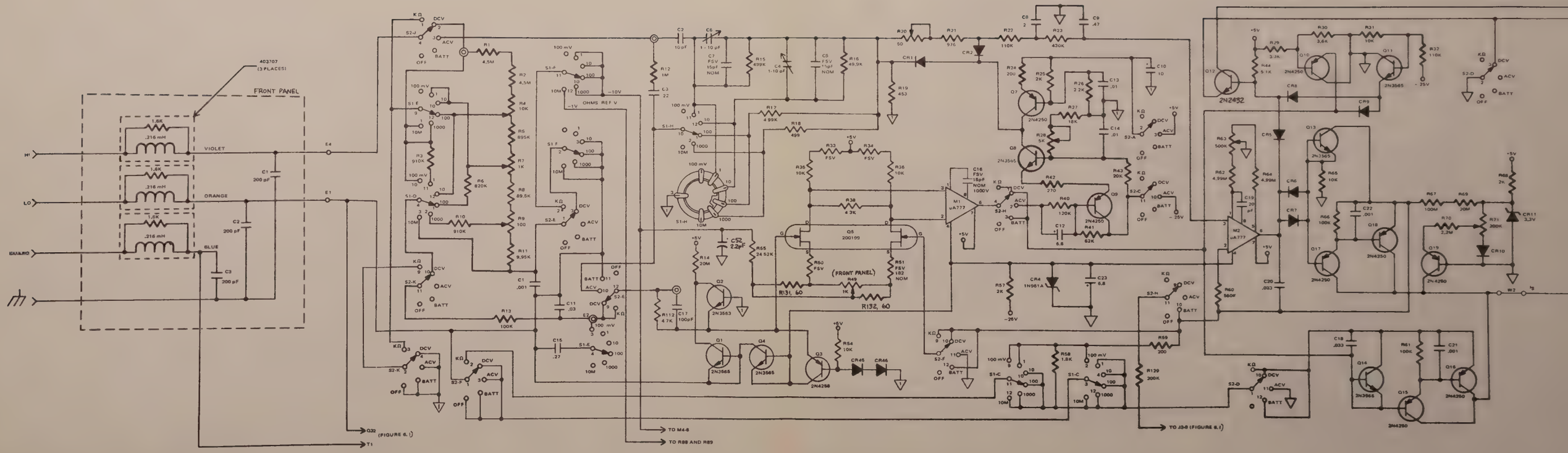


Figure 6.1 - Schematic, Power Supply



403632-F

Figure 6.2 - Layout, Main PC Board


403707
(3 PLACES)
FRONT PANEL
HI
LO
GUARD
VIOLET
ORANGE
BLUE
1.8K
.216 mH
200 pF
(FRONT PANEL)
R131, 60
R132, 60
OHMS REF V
TO M4-8
TO R88 AND R89
TO J3-8 (FIGURE 6.1)
Q32 (FIGURE 6.1)
T1
2N2432
2N4250
2N3565
2N4258
2N4290
uA777
1N961A

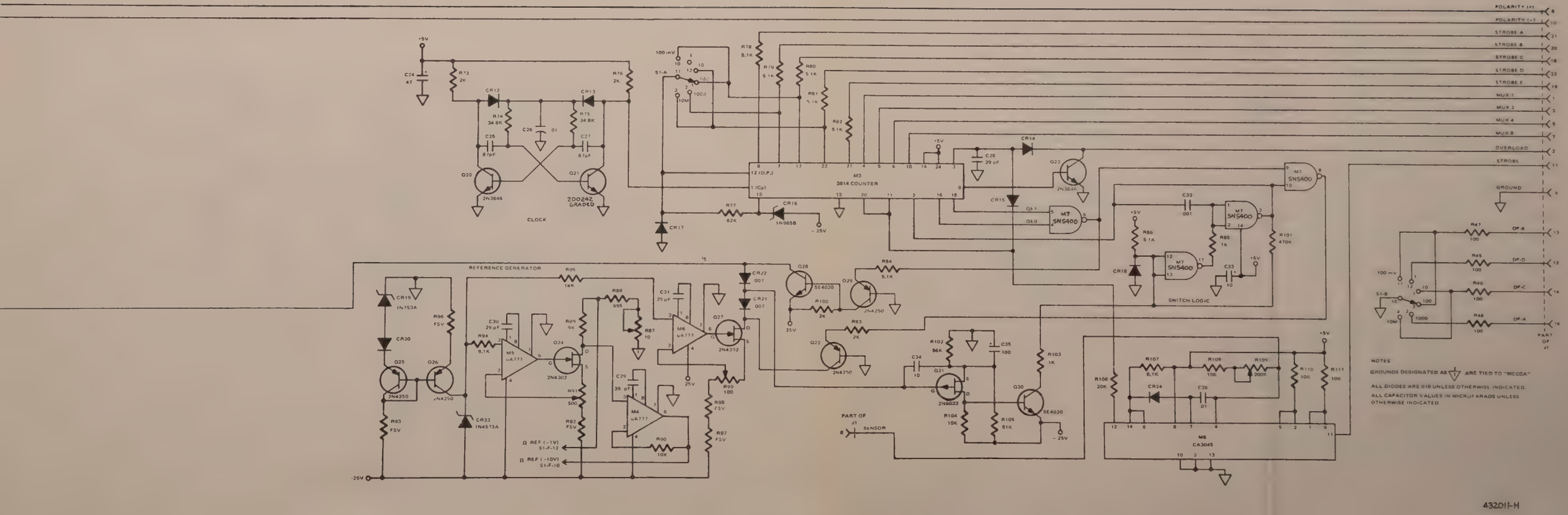
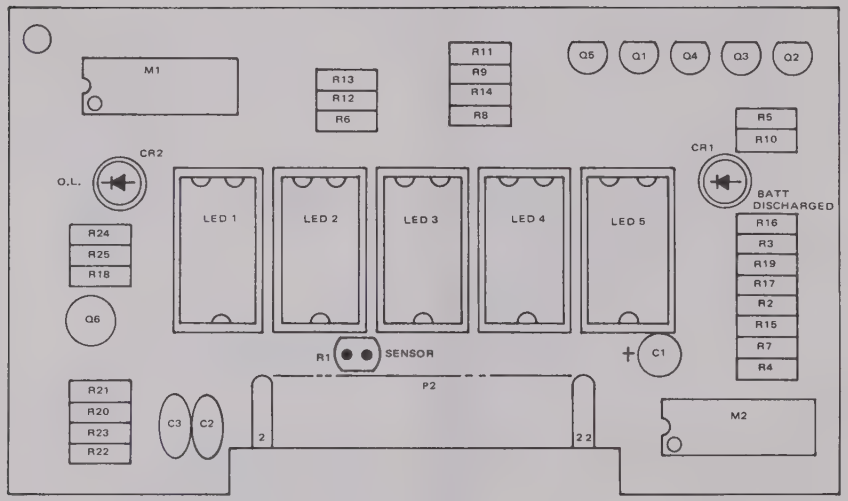


Figure 6.3 - Schematic, Main PC Board



403661-C

Figure 6.4 - Layout, Readout

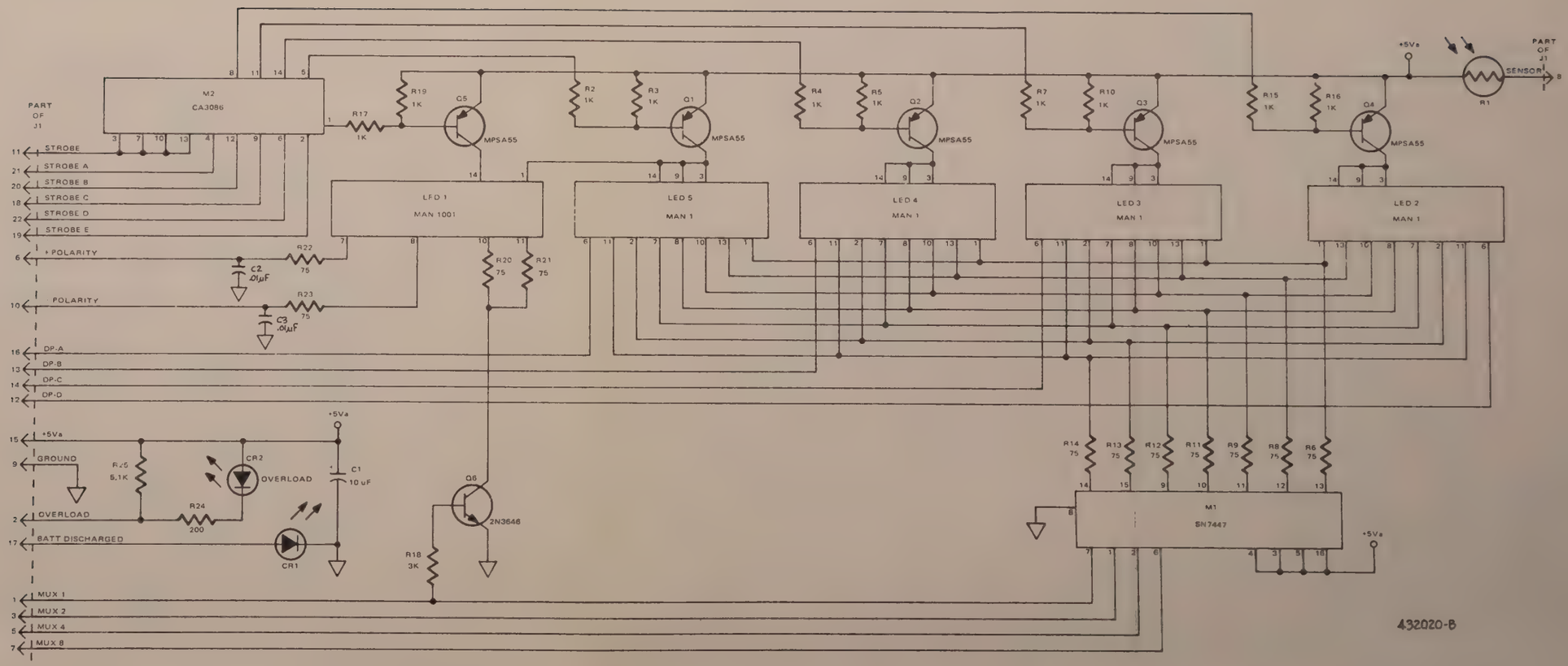


Figure 6.5 - Schematic, Readout

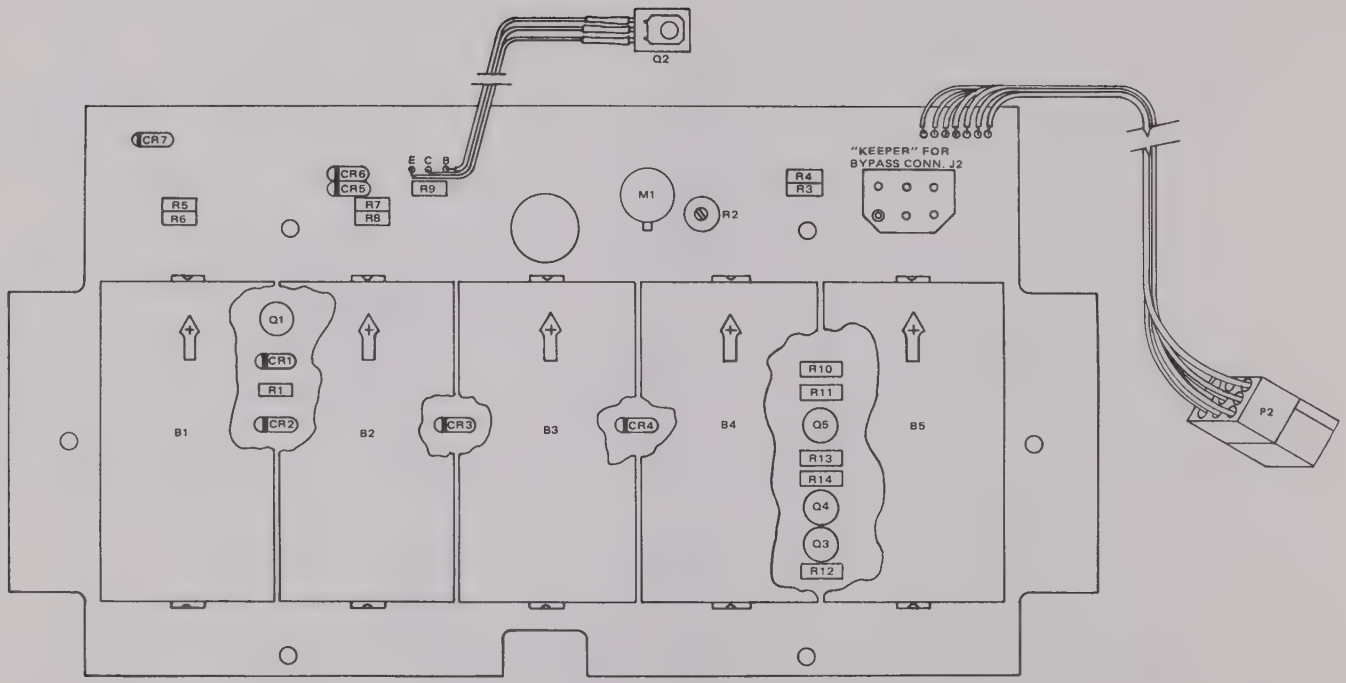


Figure 6.6 - Layout, Battery Pack

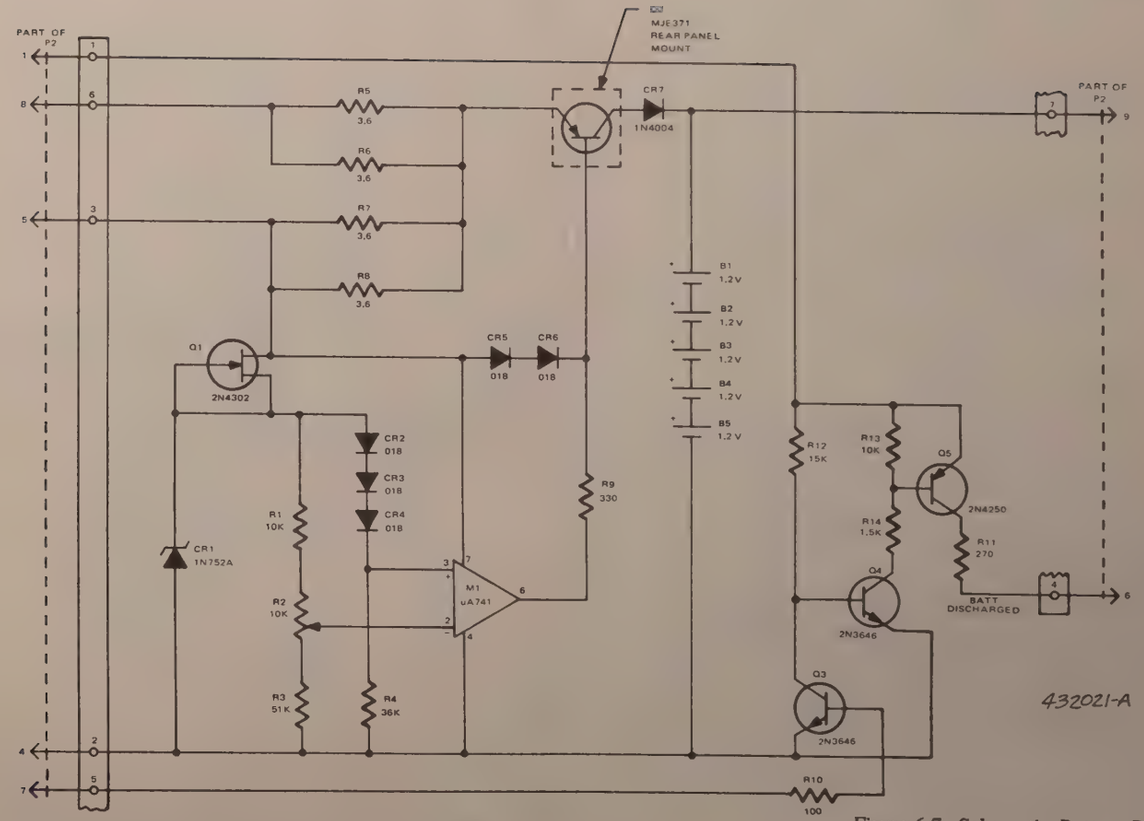
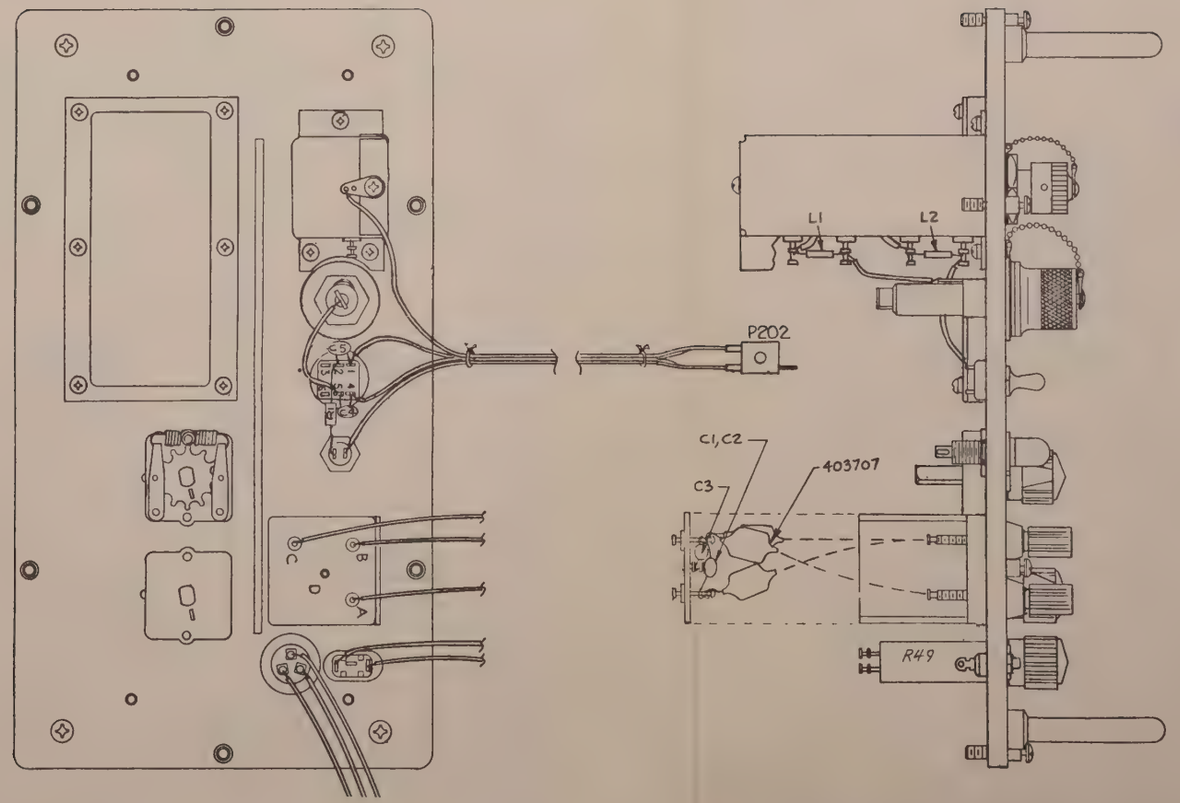
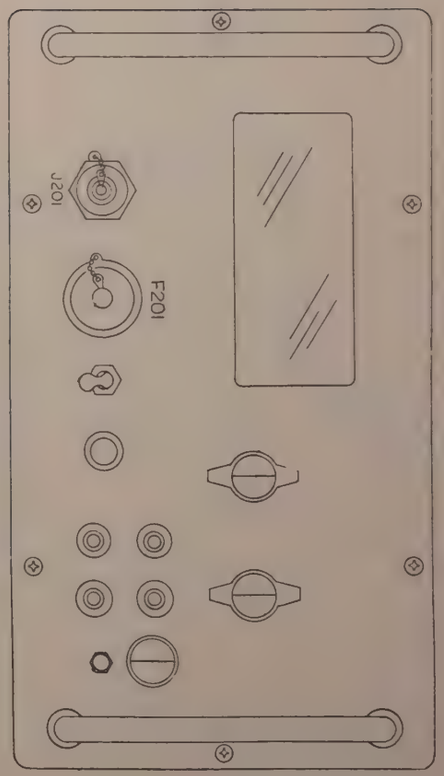


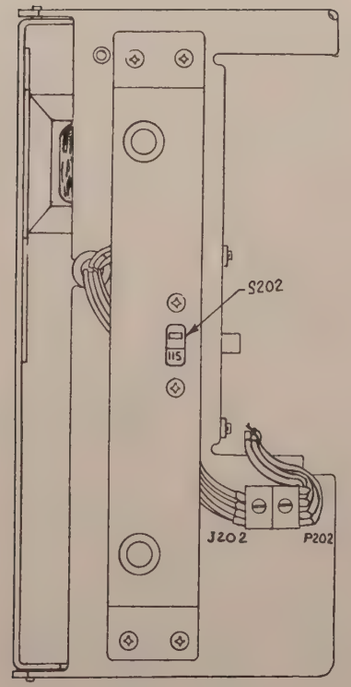
Figure 6.7 - Schematic, Battery Pack





403705-J

Figure 6.8 - Layout, Front Panel



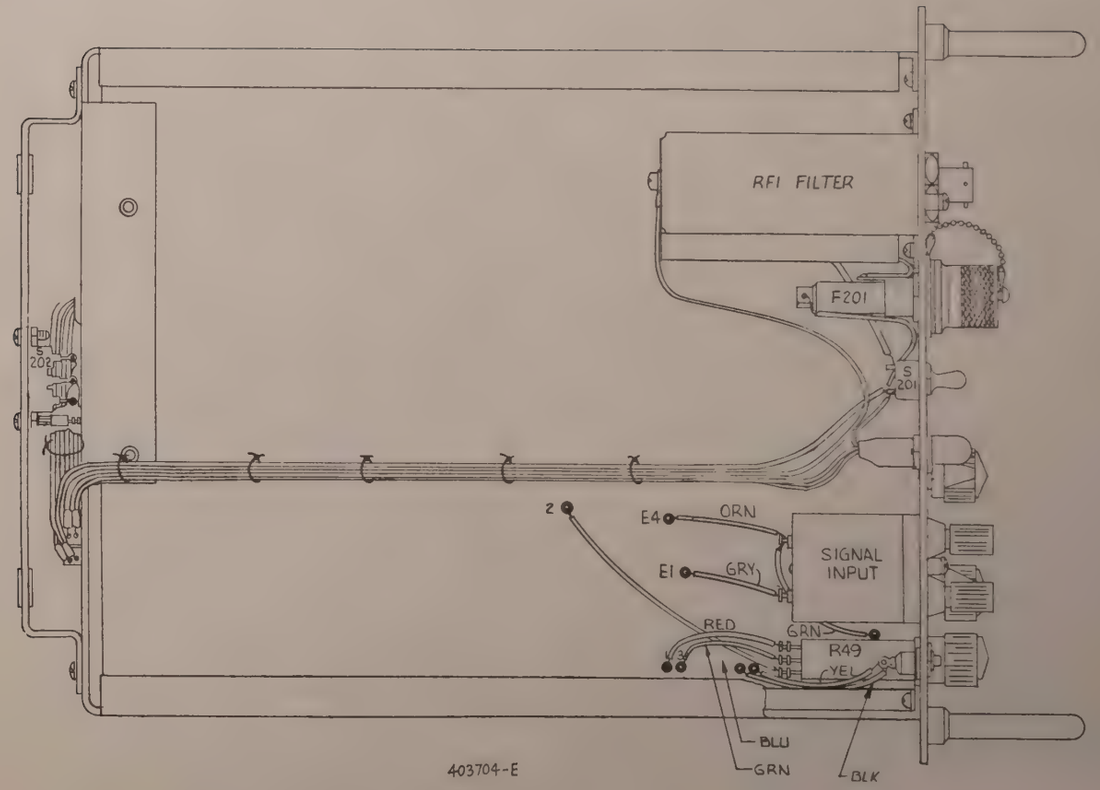


Figure 6.9 - Layout, Chassis

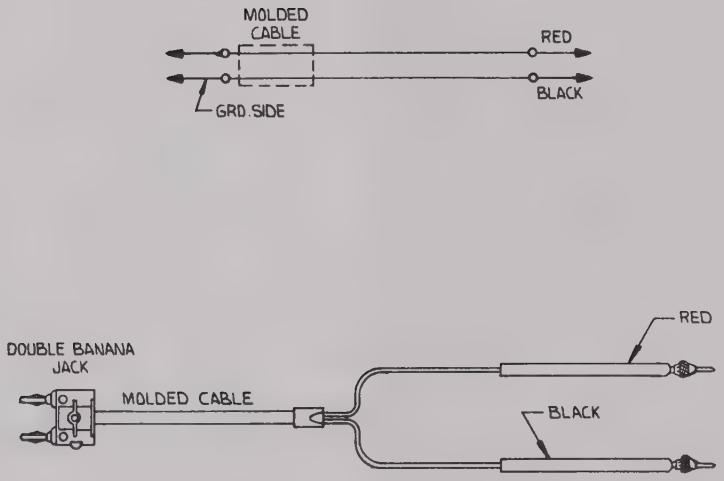


Figure 6.10 - Layout, Test Probe (Option 87)

SECTION 7 PARTS LIST

7.1 This section contains lists of replaceable parts arranged in the order of the following subassemblies:

	Page
Main Logic	7-3
Readout	7-14
Battery Pack	7-16
Chassis	7-17
Front Panel	7-18

7.2 The manufacturer's code numbers listed in Table 7.2 are from the Federal Supply Code for Manufacturers Cataloging Handbooks H4-1, H4-2, and their supplements.

7.3 Certain parts having 21793 (Dana) listed in the "FSC" column are specially-selected semiconductors. For some of these, standard commercial parts will serve as satisfactory replacements. These Dana parts are identified in table 7.1 along with the commercial equivalent.

Table 7.1

Semiconductor Type:	Equivalent:
007 Diode	Fairchild FD300
018 Diode	Texas Instruments 1N4448

Table 7.2 - List of Suppliers

FSC	NAME	FSC	NAME
00779	AMP, INC. HARRISBURG, PENNSYLVANIA	04222	AEROVOX CORP. (Hi-Q Division) MYRTLE BEACH, SOUTH CAROLINA
01121	ALLEN BRADLEY CO. MILWAUKEE, WISCONSIN	04713	MOTOROLA, INC. (Semi-Conductor Products Division) PHOENIX, ARIZONA
01295	TEXAS INSTRUMENTS, INC. DALLAS, TEXAS	05397	UNION CARBIDE CORP. (Materials Systems Division) CLEVELAND, OHIO
02111	SPECTROL ELECTRONICS CORP. CITY OF INDUSTRY, CALIFORNIA		

Table 7.2 - List of Suppliers continued

FSC	NAME
07263	FAIRCHILD SEMICONDUCTOR MOUNTAIN VIEW, CALIFORNIA
07716	TRW ELECTRONIC COMPONENTS (IRC) BURLINGTON, IOWA
08257	NPC ELECTRONICS CANOGA PARK, CALIFORNIA
09023	CORNELL-DUBILIER ELECTRONICS SANFORD, NORTH CAROLINA
10118	WINCHESTER ELECTRONICS, INC. (Litton Industries) VAN NUYS, CALIFORNIA
11237	CTS KEENE, INC. PASO ROBLES, CALIFORNIA
18178	VACTEC, INC. MARYLAND HEIGHTS, MISSOURI
18612	VISHAY RESISTOR PRODUCTS MALVERN, PENNSYLVANIA
21551	C-F ELECTRONICS, INC. VAN NUYS, CALIFORNIA
21793	DANA LABORATORIES, INC. IRVINE, CALIFORNIA
27264	MOLEX PRODUCTS CO. DOWNERS GROVE, ILLINOIS
27556	IMB ELECTRONIC PRODUCTS, INC. SANTA FE SPRINGS, CALIFORNIA
31741	GOULD-NATIONAL BATTERIES ST. PAUL, MINNESOTA
34553	AMPEREX/MEPCO-ELECTRA HAUPPAUGE, NEW YORK

FSC	NAME
50579	LITRONIX, INC. CUPERTINO, CALIFORNIA
56289	SPRAGUE ELECTRIC CO. (Pacific Division) LOS ANGELES, CALIFORNIA
71471	AEROVOX CORP. (Cinema Plant) MONCKS CORNER, SOUTH CAROLINA
72982	ERIE TECHNOLOGICAL PRODUCTS, INC. ERIE, PENNSYLVANIA
73138	BECKMAN INSTRUMENTS, INC. FULLERTON, CALIFORNIA
73445	AMPEREX ELECTRONIC CORP. HICKSVILLE, LONG ISLAND, NEW YORK
75915	LITTELFUSE, INC. DES PLAINES, ILLINOIS
80131	ELECTRONICS INDUSTRIES ASSOC. WASHINGTON, D.C.
81349	MILITARY SPECIFICATION
82389	SWITCHCRAFT, INC. CHICAGO, ILLINOIS
83125	NYTRONICS, INC. DARLINGTON, SOUTH CAROLINA
86884	RADIO CORPORATION OF AMERICA (Electronics Components Division) HARRISON, NEW JERSEY
99800	AMERICAN PRECISION INDUSTRIES, INC. (Delevan Division) EAST AURORA, NEW YORK

403632 – Assy., MAIN PC BOARD

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
C1	100071	CAP	CERAM	.001 MFD	1000 V	20%	56289	C023B102E102M
C2	100094	CAP	CERAM	10 PFD	200 V	20%	71471	HVD-3
C3	120280	CAP	MYLAR	.22 MFD	1000 V	10%	27556	ZA2J224K
C4	130077	CAP	TRIMMER	1.8-10.8 PFD	500 V		73445	2222-809-05002
C5	100060	CAP	CERAM	15 PFD	1000 V	5%	56289	C030B102E150J
C6	130077	CAP	TRIMMER	1.8-10.8 PFD	500 V		73445	2222-809-05002
C7	100060	CAP	CERAM	15 PFD	1000 V	5%	56289	C030B102E150J
C8	120266	CAP	MYLAR	2 MFD	100 V	5%	27556	XA2B205J
C9	120026	CAP	MYLAR	.47 MFD	100 V	10%	27556	SA2B474K
C10	110151	CAP	TANTA	10 MFD	35 V	20%	05397	T362C106M035A
C11	120283	CAP	POLY	.03 MFD	50 V	20%	27556	PA28303
C12	110126	CAP	TANTA	6.8 MFD	35 V	20%	05397	T368B685M035AS
C13	100063	CAP	CERAM	.01 MFD	500 V	20%	56289	5GAS-S10
C14	100063	CAP	CERAM	.01 MFD	500 V	20%	56289	5GAS-S10
C15	120282	CAP	POLY	.27 MFD	50 V	20%	27556	PA2A274
C16	100060	CAP	CERAM	15 PFD	1000 V	5%	56289	C030B102E150J
C17	101145	CAP	CERAM	100 PFD	500 V	10%	04222	TCD-DI-1N5600-100
C18	121091	CAP	MYLAR	.033 MFD	100 V	10%	09023	WMF1S33
C19	100076	CAP	CERAM	20 PFD	1000 V	5%	56289	C030B102F200J
C20	121091	CAP	MYLAR	.033 MFD	100 V	10%	09023	WMF1S33
C21	101174	CAP	CERAM	.001 MFD	500 V	10%	04222	SCD-DI-2X5F-1000
C22	101174	CAP	CERAM	.001 MFD	500 V	10%	04222	SCD-DI-2X5F-1000
C23	110126	CAP	TANTA	6.8 MFD	35 V	20%	05397	T368B685M035AS
C24	110140	CAP	TANTA	47 MFD	6 V	20%	05397	T368B476M006AS
C25	120274	CAP	POLY	87 PFD	500 V/630 V	2.5%	08257	KSO Series
C26	100063	CAP	CERAM	.01 MFD	500 V	20%	56289	5GAS-S10
C27	120274	CAP	POLY	87 PFD	500 V/630 V	2.5%	08257	KSO Series

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
C28	100030	CAP	CERAM	29 PFD	500 V	10%	71471	N-150
C29	100030	CAP	CERAM	29 PFD	500 V	10%	71471	N-150
C30	100030	CAP	CERAM	29 PFD	500 V	10%	71471	N-150
C31	100030	CAP	CERAM	29 PFD	500 V	10%	71471	N-150
C32	101174	CAP	CERAM	.001 MFD	500 V	10%	04222	SCD-DI-2X5F-1000
C33	110151	CAP	TANTA	10 MFD	35 V	20%	05397	T362C106M035A
C34	120315	CAP	POLY	10 MFD	100 V	10%	27556	DV2B106K
C35	111148	CAP	ELECT	100 MFD	25 V	20%	34553	ET101X025A5
C36	121088	CAP	MYLAR	.01 MFD	100 V	10%	09023	WMF1S1
C37	110157	CAP	ELECT	470 MFD	25 V		34553	ET471K025A01
C38	111148	CAP	ELECT	100 MFD	25 V		34553	ET101X025A5
C39	100063	CAP	CERAM	.01 MFD	500 V	20%	56289	5GAS-S10
C40	110159	CAP	TANTA	33 MFD	10 V	10%	05397	T368B336K010AS
C41	100063	CAP	CERAM	.01 MFD	500 V	20%	56289	5GAS-S10
C42	110159	CAP	TANTA	33 MFD	10 V	10%	05397	T368B336K010AS
C43	110159	CAP	TANTA	33 MFD	10 V	10%	05397	T368B336K010AS
C44	100063	CAP	CERAM	.01 MFD	500 V	20%	56289	5GAS-S10
C45	110140	CAP	TANTA	47 MFD	6 V	20%	05397	T368B476M006AS
C46	110158	CAP	TANTA	10 MFD	50 V	10%	05397	T362C106K050A
C47	110126	CAP	TANTA	6.8 MFD	35 V	20%	05397	T368B685M035AS
C48	110126	CAP	TANTA	6.8 MFD	35 V	20%	05397	T368B685M035AS
C50	110143	CAP	TANTA	1 MFD	35 V	20%	05397	T368A105M035AS
C51	110181	CAP	TANTA	47 MFD	25 V		05397	T36 -D476-025A
C52	110125	CAP	TANTA	2.2 MFD	35 V	20%	05397	T368B225M035AS
CR1	211083	DIODE	SILICO		018		21793	211083
CR2	211083	DIODE	SILICO		018		21793	211083
CR4	221254	DIODE	SILICO	ZENER	1N961B		83149	1N961B
CR5	211083	DIODE	SILICO		018		21793	211083
CR6	211083	DIODE	SILICO		018		21793	211083

403632 – Assy., MAIN PC BOARD *continued*

REF DES	DANA P/N	DESCRIPTION	FSC	MANU P/N
CR7	211083	DIODE SILICO 018	21793	211083
CR8	211083	DIODE SILICO 018	21793	211083
CR9	211083	DIODE SILICO 018	21793	211083
CR10	211083	DIODE SILICO 018	21793	211083
CR11	220031	DIODE SILICO ZENER 1/4M3.3AZ5		1/4M3.3AZ5
CR12	211083	DIODE SILICO 018	21793	211083
CR13	211083	DIODE SILICO 018	21793	211083
CR14	211083	DIODE SILICO 018	21793	211083
CR15	211083	DIODE SILICO 018	21793	211083
CR16	220022	DIODE SILICO ZENER 1N965B	81349	1N965B
CR17	211083	DIODE SILICO 018	21793	211083
CR18	211083	DIODE SILICO 018	21793	211083
CR19	220040	DIODE ZENER 1N753A	81349	1N753A
CR20	211083	DIODE SILICO 018	21793	211083
CR21	211236	DIODE SILICO 007	21793	211236
CR22	211236	DIODE SILICO 007	21793	211236
CR23	403706	DIODE ZENER 1N4573A (Part of Set, R92, R98)	21793	403706
CR24	211083	DIODE SILICO 018	21793	211083
CR25	210004	DIODE SILICO SD4 1N4004	81349	1N4004
CR26	210004	DIODE SILICO SD4 1N4004	81349	1N4004
CR27	211083	DIODE SILICO 018	21793	211083
CR28	220012	DIODE SILICO ZENER 1N958B	81349	1N958B
CR29	211083	DIODE SILICO 018	21793	211083
CR30	220027	DIODE SILICO ZENER 1N749A	81349	1N749A
CR31	211083	DIODE SILICO 018	21793	211083
CR32	211083	DIODE SILICO 018	21793	211083
CR33	211083	DIODE SILICO 018	21793	211083

403632 – Assy., MAIN PC BOARD *continued*

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
CR34	211083	DIODE	SILICO		018		21793	211083
CR35	211083	DIODE	SILICO		018		21793	211083
CR36	220027	DIODE	SILICO	ZENER	1N749A		81349	1N749A
CR37	211083	DIODE	SILICO		018		21793	211083
CR38	211083	DIODE	SILICO		018		21793	211083
CR39	220027	DIODE	SILICO	ZENER	1N749A		81349	1N749A
CR40	211083	DIODE	SILICO		018		21793	211083
CR41	211083	DIODE	SILICO		018		21793	211083
CR42	211083	DIODE	SILICO		018		21793	211083
CR43	211083	DIODE	SILICO		018		21793	211083
CR44	220033	DIODE	SILICO	ZENER	1N971B		81349	1N971B
CR45	211083	DIODE	SILICO		018		21793	211083
CR46	211083	DIODE	SILICO		018		21793	211083
J1	600632	CONN	11 PIN		4-583486-0		00779	4-583486-0
J2	600656	CONN	9 PIN		09-18-5094		27264	09-18-5094
L1	310106	CHOKE	INDUCTOR	10 UH	1537-36	10%	99800	1537-36
M1	230123	INTEGRATED CIRCUIT			UA777		21793	230123
M2	230123	INTEGRATED CIRCUIT			UA777		21793	230123
M3	230120	INTEGRATED CIRCUIT			3814		07263	3814
M4	230123	INTEGRATED CIRCUIT			UA777		21793	230123
M5	230123	INTEGRATED CIRCUIT			UA777		21793	230123
M6	230123	INTEGRATED CIRCUIT			UA777		21793	230123
M7	230128	INTEGRATED CIRCUIT			SN5400			SN5400
M8	230130	INTEGRATED CIRCUIT			CA3045F		86884	CA3045F

403632 – Assy., MAIN PC BOARD *continued*

REF DES	DANA P/N	DESCRIPTION				FSC	MANU P/N
Q1	200048	TRANS	SILICO	NPN DUAL	2N3565	80131	2N3565
Q2	200095	TRANS			2N3563	81349	2N3563
Q3	200099	TRANS			2N4258	81349	2N4258
Q4	200048	TRANS	SILICO	NPN DUAL	2N3565	80131	2N3565
Q5	200199	TRANS	DUAL		200199	21793	200199
Q7	200068	TRANS		PNP	2N4250	80131	2N4250
Q8	200043	TRANS			200043	21793	200043
Q9	200068	TRANS		PNP	2N4250	80131	2N4250
Q10	200068	TRANS		PNP	2N4250	80131	2N4250
Q11	200043	TRANS			200043	21793	200043
Q12	200059	TRANS	SILICO	PNP	2N2432A	80131	2N2432A
Q13	200048	TRANS	SILICO	NPN DUAL	2N3565	80131	2N3565
Q14	200048	TRANS	SILICO	NPN DUAL	2N3565	80131	2N3565
Q15	200068	TRANS		PNP	2N4250	80131	2N4250
Q16	200068	TRANS		PNP	2N4250	80131	2N4250
Q17	200068	TRANS		PNP	2N4250	80131	2N4250
Q18	200068	TRANS		PNP	2N4250	80131	2N4250
Q19	200068	TRANS		PNP	2N4250	80131	2N4250
Q20	200037	TRANS	SILICO	NPN	2N3646	80131	2N3646
Q21	200242	TRANS	SILICO	NPN		21793	200242
Q22	200068	TRANS		PNP	2N4250	80131	2N4250
Q23	200037	TRANS	SILICO	NPN	2N3646	80131	2N3646
Q24	200107	TRANS	N-CHAN	Field Effect	2N4302	80131	2N4302
Q25	200068	TRANS		PNP	2N4250	80131	2N4250
Q26	200068	TRANS		PNP	2N4250	80131	2N4250
Q27	200107	TRANS	N-CHAN	Field Effect	2N4302	80131	2N4302
Q28	200200	TRANS		NPN	200200	21793	200200

REF DES	DANA P/N	DESCRIPTION	FSC	MANU P/N
Q29	200068	TRANS PNP 2N4250	80131	2N4250
Q30	200200	TRANS NPN 200200	21793	200200
Q31	200185	TRANS FET 2N5033	81349	2N5033
Q32	200048	TRANS SILICO NPN DUAL 2N3565	80131	2N3565
Q33	200048	TRANS SILICO NPN DUAL 2N3565	80131	2N3565
Q34	200183	TRANS SILICO PNP MJE371	04713	MJE371
Q35	200037	TRANS SILICO NPN 2N3646	80131	2N3646
Q36	200037	TRANS SILICO NPN 2N3646	80131	2N3646
Q37	200184	TRANS PNP MPSA55	04713	MPSA55
Q38	200184	TRANS PNP MPSA55	04713	MPSA55
Q39	200184	TRANS PNP MPSA55	04713	MPSA55
Q40	200043	TRANS 200043	21793	200043
Q41	200184	TRANS PNP MPSA55	04713	MPSA55
R1	010758	RES ATTENUATOR SET	21793	010758
R2	010758	RES ATTENUATOR SET	21793	010758
R3	001807	RES CARBON 910 K 5% 1/2W		
R4	040087	POT CERMET 10 K 10%	73138	62PR10K
R5	010758	RES ATTENUATOR SET	21793	010758
R6	000824	RES CARBON 820 K 5% 1/4W	81349	RC07GF824J
R7	040123	POT CERMET 1 K 62-1-1-102	73138	62-1-1-102
R8	010758	RES ATTENUATOR SET	21793	010758
R9	040110	POT CERMET 100 OHM 62PR100	73138	62PR100
R10	000914	RES CARBON 910 K 5% 1/4W	81349	RC07GF914J
R11	010758	RES ATTENUATOR SET	21793	010758
R12	010338	RES METAL 1 MEG T-9 .1% 1W	81349	RN75E1004B
R13	030015	RES WW 100 K 1% 10W	21551	M-100

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
R14	000206	RES	CARBON	20M		5% ¼W	81349	RC07GF206J
R15	010755	RES	METAL	MATCHED SET			21793	010755
R16	010755	RES	METAL	MATCHED SET			21793	010755
R17	010755	RES	METAL	MATCHED SET			21793	010755
R18	010755	RES	METAL	MATCHED SET			21793	010755
R19	010707	RES	METAL	453 OHM		1%1/10W	81349	RN55E4530F
R20	040245	POT	CERMET	50 OHM		20% .5W	11237	360T500B
R21	010771	RES	METAL	976 OHM		1%1/10W	81349	RN55E9760F
R22	000114	RES	CARBON	110 K		5% ¼W	81349	RC07GF114J
R23	000434	RES	CARBON	430 K		5% ¼W	81349	RC07GF434J
R24	000201	RES	CARBON	200 OHM		5% ¼W	81349	RC07GF201J
R25	000202	RES	CARBON	2 K		5% ¼W	81349	RC07GF202J
R26	000222	RES	CARBON	2.2 K		5% ¼W	81349	RC07GF222J
R27	000183	RES	CARBON	18 K		5% ¼W	81349	RC07GF183J
R28	040097	POT	CERMET	5 K	62PR5K		73138	62PR5K
R29	000122	RES	CARBON	1.2 K		5% ¼W	81349	RC07GF122J
R30	000102	RES	CARBON	1 K		5% ¼W	81349	RC07GF102J
R31	000103	RES	CARBON	10 K		5% ¼W	81349	RC07GF103J
R32	000114	RES	CARBON	110 K		5% ¼W	81349	RC07GF114J
R33	010803	RES	METAL	FSV		1%	21793	010803
R34	010803	RES	METAL	FSV		1%	21793	010803
R35	010638	RES	METAL	10 K		.1%1/10W	81349	RN55E1001B
R36	010638	RES	METAL	10 K		.1%1/10W	81349	RN55E1001B
R38	000432	RES	CARBON	4.3 K		5% ¼W	81349	RC07GF432J
R39	000206	RES	CARBON	20 M		5% ¼W	81349	RC07GF206J
R40	000124	RES	CARBON	120 K		5% ¼W	81349	RC07GF124J

403632 – Assy., MAIN PC BOARD *continued*

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
R41	000623	RES	CARBON	62 K		5% 1/4W	81349	RC07GF623J
R42	000271	RES	CARBON	270 OHM		5% 1/4W	81349	RC07GF271J
R43	000203	RES	CARBON	20 K		5% 1/4W	81349	RC07GF203J
R44	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R45	000101	RES	CARBON	100 OHM		5% 1/4W	81349	RC07GF101J
R46	000101	RES	CARBON	100 OHM		5% 1/4W	81349	RC07GF101J
R47	000101	RES	CARBON	100 OHM		5% 1/4W	81349	RC07GF101J
R48	000101	RES	CARBON	100 OHM		5% 1/4W	81349	RC07GF101J
R50	010803	RES	METAL	FSV		1%	21793	010803
R51	010583	RES	METAL	182 OHM		1% 1/10W	81349	RN55C1820F
R54	000103	RES	CARBON	10 K		5% ¼W	81349	RC07GF103J
R55	010715	RES	METAL	24.52 K		.1% 1/8W	81349	RN60E
R57	000202	RES	CARBON	2 K		5% 1/4W	81349	RC07GF202J
R58	010801	RES	METAL	1.8 K		.01%	18612	V-53-1
R59	010800	RES	METAL	200 OHM		.01%	18612	V-53-1
R60	000564	RES	CARBON	560 K		5% 1/4W	81349	RC07GF564J
R61	000104	RES	CARBON	100 K		5% 1/4W	81349	RC07GF104J
R62	011178	RES	CARBON	4.99 K		1% ½W	81349	RN20X4994F
R63	040159	POT	CERMET	500 K		30% ½W	73138	62PR500K
R64	011178	RES	CARBON	4.99 K		1% 1/4W	81349	RN20X4994F
R65	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R66	000104	RES	CARBON	100 K		5% 1/4W	81349	RC07GF104J
R67	000107	RES	CARBON	100 M		5% 1/4W	81349	RC07GF107J
R68	000202	RES	CARBON	2 K		5% 1/4W	81349	RC07GF202J
R69	000206	RES	CARBON	20 M		5% 1/4W	81349	RC07GF206J
R70	000225	RES	CARBON	2.2 M		5% 1/4W	81349	RC07GF225J
R71	040067	POT		200 K	62PR200K		73138	62PR200K

403632 – Assy., MAIN PC BOARD *continued*

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
R73	000202	RES	CARBON	2 K		5% 1/4W	81349	RC07GF202J
R74*	010635	RES	METAL	34.8 K		1% 1/10W	81349	RN55C3482F
R75*	010635	RES	METAL	34.8 K		1% 1/10W	81349	RN55C3482F
R76	000202	RES	CARBON	2 K		5% 1/4W	81349	RC07GF202J
R77	000623	RES	CARBON	62 K		5% 1/4W	81349	RC07GF623J
R78	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R79	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R80	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R81	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R82	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R83	000202	RES	CARBON	2 K		5% 1/4W	81349	RC07GF202J
R84	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R85	000102	RES	CARBON	1 K		5% 1/4W	81349	RC07GF102J
R86	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R87	040183	POT	CERMET	10 OHM	62PR10	30%	73138	62PR10
R88	010758	RES	ATTENUATOR SET		010758		21793	010758
R89	010758	RES	ATTENUATOR SET		010758		21793	010758
R90	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R91	040093	POT	WW	500 OHM	50-3-1-501		02111	50-3-1-501
R92	403706	RES	(P/O Sel. Set)	FSV			21793	403706
R93	001737	RES	CARBON	FSV		5% ¼W	21793	001737
R94	000912	RES	CARBON	9.1 K		5% 1/4W	81349	RC07GF912J
R95	000183	RES	CARBON	18 K		5% 1/4W	81349	RC07GF183J
R96	010799	RES	METAL FSV	6K - 7.5 K		1%	21793	010799
R97	010803	RES	METAL FSV			1%	21793	010803
R98	403706	RES	(P/O Sel. Set)	FSV			21793	403706
R99	040028	POT	WW	100 OHM	51-3-11-101		02111	51-3-11-101

*50 Hz Operation R74 and R75 are:

010940	RES	METAL	28 K	1%	81349	RN55C2802F

403632 – Assy., MAIN PC BOARD *continued*

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
R100	000202	RES	CARBON	2 K		5% 1/4W	81349	RC07GF202J
R101	000474	RES	CARBON	470 K		5% 1/4W	81349	RC07GF474J
R102	000563	RES	CARBON	56 K		5% 1/4W	81349	RC07GF563J
R103	000102	RES	CARBON	1 K		5% 1/4W	81349	RC07GF102J
R104	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R105	000513	RES	CARBON	51 K		5% 1/4W	81349	RC07GF513J
R106	000203	RES	CARBON	20 K		5% 1/4W	81349	RC07GF203J
R107	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R108	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R109	040067	POT		200 K	62PR200K		73138	62PR200K
R110	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R111	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R112	000472	RES	CARBON	4.7 K		5% 1/4W	81349	RC07GF472J
R114	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R115	000102	RES	CARBON	1 K		5% 1/4W	81349	RC07GF102J
R116	000152	RES	CARBON	1.5 K		5% 1/4W	81349	RC07GF152J
R117	040123	POT	CERMET	1 K	62-1-1-102		73138	62-1-1-102
R118	000300	RES	CARBON	30 OHM		5% 1/4W	81349	RC07GF300J
R119	000750	RES	CARBON	75 OHM		5% 1/4W	81349	RC07GF750J
R120	000272	RES	CARBON	2.7 K		5% 1/4W	81349	RC07GF272J
R121	000241	RES	CARBON	240 OHM		5% 1/4W	81349	RC07GF241J
R122	000750	RES	CARBON	75 OHM		5% 1/4W	81349	RC07GF750J
R123	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R124	040115	POT	CERMET	500 OHM	62PR500	10%	73138	62PR500
R125	000272	RES	CARBON	2.7 K		5% 1/4W	81349	RC07GF272J
R126	000821	RES	CARBON	820 OHM		5% 1/4W	81349	RC07GF821J
R127	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J

403632 – Assy., MAIN PC BOARD *continued*

REF DES	DANA P/N	DESCRIPTION	FSC	MANU P/N
R128	000101	RES CARBON 100 OHM 5% 1/4W	81349	RC07GF101J
R129	010618	RES METAL 200 K .25% 1/10W	81349	RN55C2003C
R130	001771	RES CARBON 1.8 OHM 5% 1/2W	01121	See Descrpt.
R131	010603	RES METAL 60.4 OHM 1% 1/10W	81349	RN55C60R4F
R132	010603	RES METAL 60.4 OHM 1% 1/10W	81349	RN55C60R4F
S1	600647	WAFER Assy., RANGE 600647	21793	600647
S2	600648	WAFER Assy., FUNCTION 600648	21793	600648
T1	300074	TRANSFORMER, POWER	21793	300074
T2	403634	TRANSFORMER Assy., INVERTER 403634	21793	403634
W1	600245	JUMPER L-2007-1LP		L-2007-1LP
W2	600245	JUMPER L-2007-1LP		L-2007-1LP

403661 – Assy., PCB, READOUT

REF DES	DANA P/N	DESCRIPTION	FSC	MANU P/N
C1	110184	CAP TANT 10 MFD 25 V	05397	T368B106K025AS
C2	100017	CAP CERAM .01 MFD 100 V 20%	56289	C023B101F103M
C3	100017	CAP CERAM .01 MFD 100 V 20%	56289	C023B101F103M
CR1	210045	DIODE L.E.D. RITE LITE 21	50579	RITE LITE 21
CR2	210045	DIODE L.E.D. RITE LITE 21	50579	RITE LITE 21
LED 1	210044	DIODE L.E.D. DISPLAY DISPLAY ± 1	50579	DL-101A
LED 2	210043	DIODE L.E.D. DISPLAY DISPLAY 0-9	50579	DL-10A
LED 3	210043	DIODE L.E.D. DISPLAY DISPLAY 0-9	50579	DL-10A
LED 4	210043	DIODE L.E.D. DISPLAY DISPLAY 0-9	50579	DL-10A
LED 5	210043	DIODE L.E.D. DISPLAY DISPLAY 0-9	50579	DL-10A
M1	230129	INTEGRATED CIRCUIT SN5447	01295	SN5447
M2	230130	INTEGRATED CIRCUIT CA3045F	86884	CA3045F
Q1	200184	TRANS PNP MPSA55	04713	MPSA55
Q2	200184	TRANS PNP MPSA55	04713	MPSA55
Q3	200184	TRANS PNP MPSA55	04713	MPSA55
Q4	200184	TRANS PNP MPSA55	04713	MPSA55
Q5	200184	TRANS PNP MPSA55	04713	MPSA55
Q6	200037	TRANS SILICO NPN 2N3646	80131	2N3646
R1	920639	PHOTO CELL LIGHT SENSOR	18178	VT904
R2	000102	RES CARBON 1 K 5% 1/4W	81349	RC07GF102J
R3	000102	RES CARBON 1 K 5% 1/4W	81349	RC07GF102J
R4	000102	RES CARBON 1 K 5% 1/4W	81349	RC07GF102J

403661 – Assy., PCB, READOUT *continued*

REF DES	DANA P/N	DESCRIPTION				FSC	MANU P/N
R5	000102	RES	CARBON	1 K	5% 1/4W	81349	RC07GF102J
R6	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R7	000102	RES	CARBON	1 K	5% 1/4W	81349	RC07GF102J
R8	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R9	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R10	000102	RES	CARBON	1 K	5% 1/4W	81349	RC07GF102J
R11	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R12	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R13	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R14	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R15	000102	RES	CARBON	1 K	5% 1/4W	81349	RC07GF102J
R16	000102	RES	CARBON	1 K	5% 1/4W	81349	RC07GF102J
R17	000102	RES	CARBON	1 K	5% 1/4W	81349	RC07GF102J
R18	000302	RES	CARBON	3 K	5% 1/4W	81349	RC07GF302J
R19	000102	RES	CARBON	1 K	5% 1/4W	81349	RC07GF102J
R20	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R21	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R22	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R23	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R24	000201	RES	CARBON	200 OHM	5% 1/4W	81349	RC07GF201J
R25	000512	RES	CARBON	5.1 K	5% 1/4W	81349	RC07GF512J

403663 – Assy., PCB, BATTERY PACK OPTION

REF DES	DANA P/N	DESCRIPTION	FSC	MANU P/N
B1	920650	BATTERY LOW TEMP 1.25 V	31741	4.0SCL (Lo Temp)
B2	920650	BATTERY LOW TEMP 1.25 V	31741	4.0SCL (Lo Temp)
B3	920650	BATTERY LOW TEMP 1.25 V	31741	4.0SCL (Lo Temp)
B4	920650	BATTERY LOW TEMP 1.25 V	31741	4.0SCL (Lo Temp)
B5	920650	BATTERY LOW TEMP 1.25 V	31741	4.0SCL (Lo Temp)
CR1	220019	DIODE SILICO ZENER 1N752A	81349	1N752A
CR2	211083	DIODE SILICO 018	21793	211083
CR3	211083	DIODE SILICO 018	21793	211083
CR4	211083	DIODE SILICO 018	21793	211083
CR5	211083	DIODE SILICO 018	21793	211083
CR6	211083	DIODE SILICO 018	21793	211083
CR7	210004	DIODE SILICO 1N4004	81349	1N4004
M1	230166	INTEGRATED CIRCUIT UA741	07263	U5B7741312
Q1	200107	TRANS N-CHAN FIELD EFFECT	80131	2N4302
Q2	200183	TRANS SILICO PNP MJE371	04713	MJE371
Q3	200037	TRANS SILICO NPN 2N3646	80131	2N3646
Q4	200037	TRANS SILICO NPN 2N3646	80131	2N3646
Q5	200068	TRANS PNP 2N4250	80131	2N4250
R1	000103	RES CARBON 10 K 5% 1/4W	81349	RC07GF103J
R2	040087	RES POT 10 K 10%	73138	62PR10K
R3	000513	RES CARBON 51 K 5% 1/4W	81349	RC07GF513J
R4	000363	RES CARBON 36 K 5% 1/4W	81349	RC07GF363J
R5	001733	RES CARBON 3.6 OHM 5% 1/4W	01121	See Descrpt.

NOTE: A satisfactory replacement for special Dana diode 018 is TI 1N4448.

403663 – Assy., PCB, BATTERY PACK OPTION *continued*

REF DES	DANA P/N	DESCRIPTION				FSC	MANU P/N
R6	001733	RES	CARBON	3.6 OHM	5% 1/4W	01121	See Descrpt.
R7	001733	RES	CARBON	3.6 OHM	5% 1/4W	01121	See Descrpt.
R8	001733	RES	CARBON	3.6 OHM	5% 1/4W	01121	See Descrpt.
R9	000331	RES	CARBON	330 OHM	5% 1/4W	81349	RC07GF331J
R10	000101	RES	CARBON	100 OHM	5% 1/4W	81349	RC07GF101J
R11	000271	RES	CARBON	270 OHM	5% 1/4W	81349	RC07GF271J
R12	000153	RES	CARBON	15 K	5% 1/4W	81349	RC07GF153J
R13	000103	RES	CARBON	10 K	5% 1/4W	81349	RC07GF103J
R14	000152	RES	CARBON	1.5 K	5% 1/4W	81349	RC07GF152J

403704 – Assy., CHASSIS

REF DES	DANA P/N	DESCRIPTION	FSC	MANU P/N
J202	600326	CONN	10118	JP3P-1S-AC
S202	600521	SWITCH DPDT	82389	46256LFR

403705 – Assy., FRONT PANEL

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
C1	100040	CAP	CERAM	200 PFD	1 KV	20%	56289	C023B102E201M
C2	100040	CAP	CERAM	200 PFD	1 KV	20%	56289	C023B102E201M
C3	100045	CAP	CERAM	.02 MFD	1 KV	20%	72982	841-000-Z5U0203M
C4	100045	CAP	CERAM	.02 MFD	1 KV	20%	72982	841-000-Z5U0203M
C5	100045	CAP	CERAM	.02 MFD	1 KV	20%	72982	841-000-Z5U0203M
F201	920756	FUSE, SLO BLOW		1/4 A	250 V		75915	MDL1/4
L1	310119	INDUCTOR					83125	
L2	310119	INDUCTOR					83125	
P202	600327	CONN	3 S	1 P			10118	JP3S-1P-ACD
R1	001764	RES	CARBON	62 K		5% 1/2W	Liberty	See Descrpt.
R49	040294	POT	WW	1 K		5%	07716	5000

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